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TICK-BORNE LIVESTOCK DISEASES AND THEIR VECTORS

1. The global problem

This article is the first of a series of five on the control of tick-borne diseases and their vectors. Subsequent articles will consider the epizootiology of some of the tick-borne diseases; the Australian methods of immunization against anaplasmosis and babesiosis; the chemical control of ticks; and acaricide resistance and alternate methods of tick control.

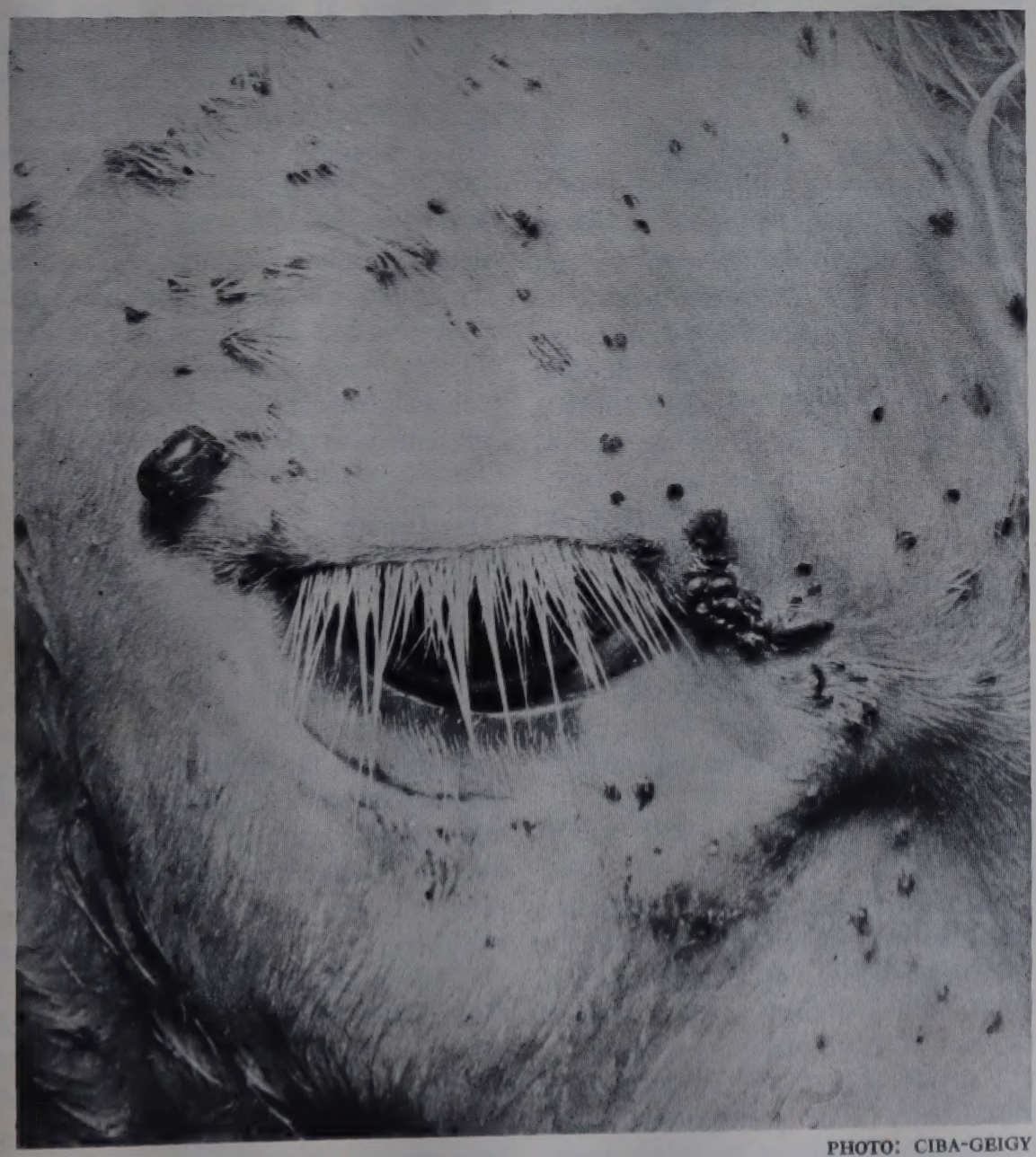

PHOTO: CIBA-GEIGY

Cow's face infested with various stages of Boophilus microplus

by Ralph A. Bram

The tick-borne diseases of livestock constitute a complex of several diseases whose etiological agents may be protozoal, rickettsial, bacterial or viral; their single common feature is that they can all be transmitted by ticks. Tick-borne diseases are present throughout the world, but are most numerous and exert their greatest impact in the tropical and subtropical regions.

In many countries, they are the major health impediments to efficient livestock production. On a global basis, the economic toll caused by tick-borne diseases is staggering. Better global control of tick-borne diseases of livestock and their vectors would contribute substantially to improved meat and milk production (Barnett, 1974a and 1974b).

Although over 60 tick-borne agents may be pathogenic to livestock throughout the world, relatively few are recognized as being of economic significance. The following is a brief

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resumé of the major tick-borne haemotropic diseases.

Babesiosis

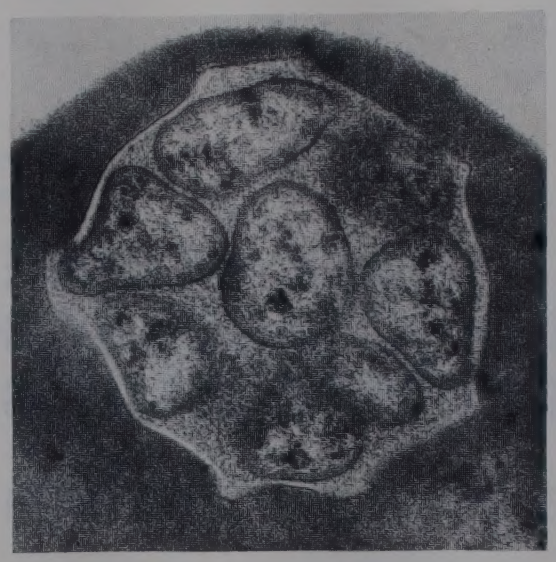
Babesiosis, or tick fever, is a febrile disease of domestic and wild animals characterized by extensive erythrocytic lysis leading to anaemia, icterus and haemoglobinuria, and which can be fatal. The disease is caused by protozoan parasites of the genus *Babesia* transmitted by a variety of tick species. There are at least 14 distinct species of *Babesia* from various vertebrate hosts (Riek, 1968). In cattle, *Babesia bigemina* is distributed through Central and South America, Europe, Africa, Australia and Asia; *Babesia bovis* has been reported from Europe, Africa, Asia and the Far East; *Babesia argentina* (which may be synonymous with *B. bovis*) is found in southeast Asia and Australia, and from Mexico down through Latin America.

The successful treatment of babesiosis depends on early diagnosis and prompt administration of a number of drugs. This is particularly difficult where range cattle are involved. Protection depends on premunition (with or without specific chemotherapy) and continued exposure to infected ticks in order to maintain the protection established by inoculation. Prevention of babesiosis in enzootic areas depends on the elimination of the tick vector by regular dipping of cattle with an acaricide at intervals of two weeks or less, depending on the local ecology of vector species.

The eradication of Texas cattle fever (caused by *Babesia bigemina*) was accomplished in the United States by the elimination of the tick vectors *Boophilus microplus* and *Boophilus annulatus*.

Bovine anaplasmosis

Bovine anaplasmosis is an infectious, noncontagious haemotropic disease of cattle characterized in the acute form by fever, anaemia, weakness, constipation, yellowing of the mucous membranes, lack of appetite, depression, dehydration, and laboured breathing. Animals surviving an acute attack often make a slow recovery, resulting in losses in milk or meat production. Generally, mortality is between 5 and 40 percent, but may reach 70 percent during a severe outbreak. The causative agent, *Anaplasma marginale*, may be biologically transmitted by 20 or more species of ticks and may also be mechanically transmitted by a variety of biting fly species, particularly horse flies of the family Tabanidae.



Electron micrograph of a bovine erythrocyte infected with Anaplasma marginale *(courtesy R.L. Sealock, Animal Parasitology Institute, ARS-USDA)*

Anaplasmosis is present in most tropical and subtropical regions, and is also found in some temperate areas. The epizootiology of anaplasmosis is complicated by the life-long carrier state which occurs in animals that have recovered from the clinical disease. As with babesiosis, treatment of anaplasmosis depends on early diagnosis and prompt administration of an appropriate drug. Anaplasmosis immunization, using either killed vaccine, attenuated live vaccine, or live *Anaplasma centrale* vaccine, has been practised with varying results in many parts of the world.

East Coast fever

East Coast fever is a cattle disease caused by the protozoan parasite *Theileria parva*. Recent research in east Africa indicates that virulent strains of *Theileria mutans* may also be involved in the East Coast fever syndrome. The pathogen is transstadially transmitted by at least nine tick species; however, the principal vector is the brown ear tick, *Rhipicephalus appendiculatus*. East Coast fever is enzootic in east Africa and has been reported from Tanzania, Kenya, Uganda, Mozambique, South Africa, Rhodesia, Zaire, Rwanda, Burundi, Malawi and the Sudan. The disease probably exists in Ethiopia, Zambia and southern Somalia. South Africa and Mozambique have reportedly eradicated the disease through tick control.

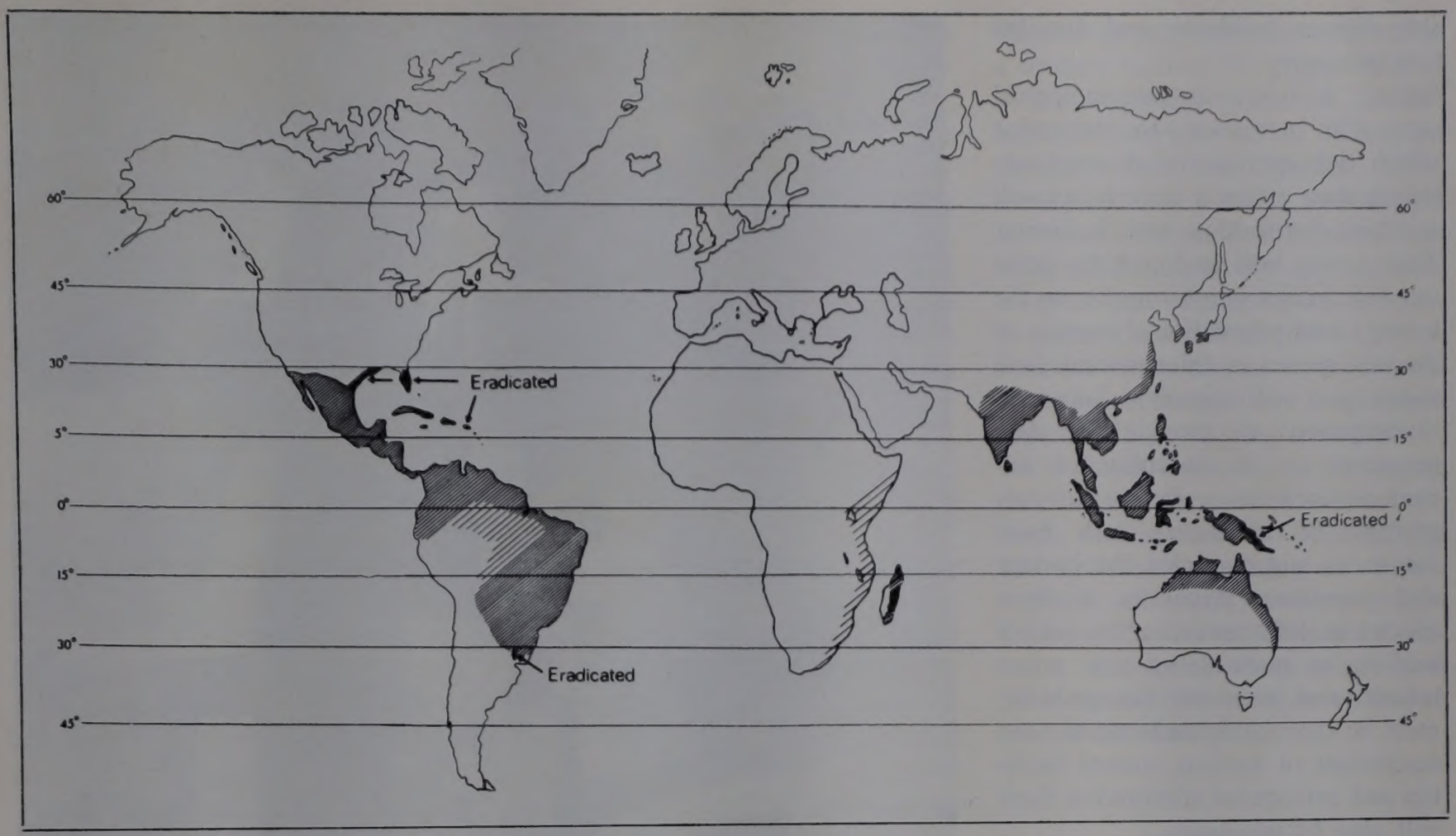
No practical therapy exists for East Coast fever. Although great progress is being made in the development of a method of immunization by a UNDP-supported regional project in Muguga, Kenya, for which FAO is the executing agency (Cunningham, 1974), no practical technique is yet available for widespread application. Control of East Coast fever depends, therefore, on preventive tick control by frequent spraying or dipping of cattle using an appropriate acaricide, preferably at intervals of less than seven days depending on the vector species and its biology in different geographical areas.

Other species of *Theileria* act as causal agents of theileriasis in a number of mammalian hosts. Of particular note is *Theileria annulata*, which has a broad geographical distribution and numerous strains with a wide range of virulence. An excellent review of theileriasis has been presented by Barnett (1968).

Heartwater

Heartwater is a septicaemic, infectious disease of cattle, as well as of sheep, goats and other ruminants. The causative agent is a rickettsia, *Rickettsia ruminantium*, which is transmitted by ticks of the genus *Amblyomma*. The enzootic areas of the disease correspond to the distribution of the vector species in southern, eastern and western African countries and in Madagascar. It has also been reported from the Sudan.

Treatment of heartwater with one of several appropriate drugs will result in recovery of a large proportion of infected animals if applied early in the disease. Immunization for heartwater has been used in enzootic re-



Distribution of Boophilus microplus *(after Wharton, 1974)*

gions for a number of years. It is now common in some areas to infect animals deliberately, and apply chemotherapeutic agents upon the first appearance of symptoms of the disease. Attempts have been made to control heartwater by the eradication of the vector species, but this has proved to be a formidable task. Other incompletely defined tick-borne rickettsial pathogens of livestock have also been recognized.

Tick-borne virus diseases

A number of tick-borne virus diseases exist which are generally more regional than the diseases of haemoprotozoal etiology. Several viruses, mainly in the Togavirus group, are known to be spread by ticks as well as other arthropods. These are currently under investigation. Nairobi sheep disease, which has recently been found to be identical with Ganjam virus in India, is a widespread tick-borne disease in east Africa. Louping ill is a tick-borne virus disease affecting cattle and sheep in northern England and Scotland, and it has been reported from the U.S.S.R. and Czechoslovakia. Ticks of the genus *Ornithodoros* may be significant in the transmission of African swine fever virus from feral to domestic swine; however, other means of spread are of even greater significance, particularly when the disease is introduced into a new area.

Economic losses

In addition to being efficient vectors of disease agents, ticks cause grave economic damage in certain areas. For example, it has been estimated that there is a loss of 1-3 ml of blood for every cattle tick completing its life cycle on an animal. Furthermore, tick infestations cause irritation, damage hides, and predispose animals to bacterial and fungal infections, as well as screw-worm attack, in the wounds left by tick bites. Recent studies in Australia indicate that the total annual loss caused by the cattle tick amounts to about A$5 per head of cattle, or 4 percent of the gross value of cattle slaughtered in 1972/73.

FAO is encouraging countries to intensify their efforts to control ticks and tick-borne diseases, in order to improve the efficiency of livestock production. As a general principle, control should be organized as a responsibility of government animal health authorities; decisions affecting control initiatives would thus be made within the perspective of a country's total animal health commitment.

Before intensification of tick and tick-borne disease control can begin, several preliminary criteria should be satisfied. First, a countrywide survey must be made to determine the incidence and distribution of the various tick-borne diseases. An economic assessment of the benefits expected from improved control should be made at the same time. In addition to the classical blood smear examination for the detection of haemoprotozoa, modern serodiagnostic techniques — such as the fluorescent antibody tests, card agglutination tests, complement-fixation reactions and immunodiffusion tests — should be utilized whenever possible to de-

fine disease incidence and distribution precisely.

Second, a systematic entomological survey is necessary to determine which tick species are of veterinary significance within a country, as well as their distribution and incidence. This survey will undoubtedly point out deficiencies in information on the biology and population dynamics of the tick species in different ecological zones, and will stimulate long-term investigations to provide the data necessary for the execution of tick control activities. Before a programme is considered, such basic factors as target species, the biology and population dynamics of these species in different areas, the role of wildlife in maintaining tick populations, and acaricide susceptibility, must be thoroughly understood. An assessment of existing control facilities and anticipated additions to these will also be necessary.

A comprehensive plan should be developed for a coordinated, country-wide control scheme. On the basis of the preliminary epizootiological and entomological information (such as that developed by Mahoney and Ross, 1972), decisions can be made concerning such basic considerations as the application of immunization techniques, possibilities for treatment, methods of tick control, necessity for limiting animal movements and establishment of tick eradication zones. These decisions will also be tempered by the availability of financial and manpower resources and technical expertise, and by the economic benefits expected from the control scheme.

The possibility of including large-scale immunization in a control programme will obviously depend on the diseases to be controlled. Operationally effective methods of immunization are available only for babesiosis and anaplasmosis, and even these have their shortcomings. If the total control scheme includes tick and disease eradication zones, present methods of immunization are excluded from these areas.

Methods of treatment may be available, but impractical for large-scale application because of management practices. For example, early treat-

Cattle emerging from acaricide dip vat in Tanzania

ment of a producing dairy animal for babesiosis infection is possible, whereas treatment of a beef animal under range conditions would be difficult, if not impossible.

Although chemical control of ticks will, for the foreseeable future, form the basis of any control programme, alternate methods of control should also be incorporated whenever feasible. Raising tick-resistant cattle, adopting special management techniques and practising strategic dipping are all methods which belong in a fully integrated programme (Wharton, 1974).

Eradication

In some programmes, quarantine regulations must be established to control the movements of infected animals. This is particularly important when tick eradication in defined zones is planned. In general, nationwide tick or protozoal tick-borne disease eradication is not to be encouraged as a programme objective in developing countries. Usually, programmes which aim to achieve eradication eventually falter, with the result that large populations of susceptible livestock are left unprotected and subsequently succumb to one of the tick-borne diseases. The result can be an epizootic of major proportions. As recently as 1973, the Australian Cattle Tick Control Commission Inquiry concluded that eradication of the cattle tick on a national basis was not practicable in that country; it did, however, indicate that eradication on a regional basis in certain parts of Australia was feasible. On the other hand, Mexico has just established a major eradication programme based on sound scientific principles and with the strong financial and organizational support of the Government. A national tick or tick-borne disease eradication effort should only be attempted when a long-term commitment of finances, manpower and dedication is assured.

On a global basis, the FAO Animal Production and Health Division is increasing its efforts to promote and coordinate improved tick and tick-borne disease control. Immediate objectives will concentrate on improving methods of vector control, treatment and immunization; the long-term objective will be to integrate these improved techniques into effective disease control programmes. Over 14 regional and country projects, which are supported by the United Nations Development Programme with FAO as the executing agency, will continue to provide basic information and operational applications in different regions. Additional projects will continually be developed and implemented.

On the basis of recommendations of the FAO Expert Consultation on Research on Tick-borne Diseases and their Vectors (FAO, 1975a) and the Joint FAO/Industry Task Force on Tick and Tick-borne Disease Control (FAO, 1975b), a Global Acaricide Resistance Monitoring Programme is being planned as a Regular Programme activity of the Animal Health Service. Major features of this programme include: (1) FAO Acaricide Resistance Test Kits, to be distributed to cooperating countries; (2) establishment of a World Acaricide Resistance Reference Centre which will provide cooperating countries with baseline data for registered acaricides; and (3) the annual dissemination of data on the global status of acaricide resistance.

Finally, also as a result of recommendations of the Expert Consultation, FAO intends to increase its activities in information dissemination. The existing FAO Information Circular on Tick-borne Diseases of Livestock will be continued and expanded; a practical field manual on the control of ticks and tick-borne diseases is in the planning stage; and efforts are being made to establish practical, field-oriented training courses on the control of ticks and tick-borne diseases of livestock.

Summary

Such tick-borne diseases as babesiosis, bovine anaplasmosis, East Coast fever and heartwater cause severe economic damage to livestock production. Control of tick-borne diseases within a country requires the preparation of a comprehensive plan for coordinated, countrywide action. The plan should include immunization, treatment and tick control, and should be based on scientifically sound data collected during preliminary epizootiological and entomological surveys. In general, nationwide tick or protozoal tick-borne disease eradication is not to be encouraged as a programme objective in developing countries.

On a global basis, FAO is increasing its efforts to promote tick and tick-borne disease control. This will be accomplished by existing and future regional and country projects; establishment of a Global Acaricide Resistance Monitoring Programme; and the increased dissemination of disease control information.

REFERENCES

BARNETT, S.F. 1968. Theileriasis. *In* Weinman, D. and Ristic, M. *Infectious blood diseases of man and animals.* II, p. 269-328. New York, Academic Press.

BARNETT, S.F. 1974a. Economical aspects of protozoal tick-borne diseases in livestock in parts of the world other than Britain. *Bull. Off. int. Epiz.*, 81(1-2): 183-196.

BARNETT, S.F. 1974b. Economical aspects of tick-borne disease control in Britain. *Bull. Off. int. Epiz.*, 81(1-2): 167-182.

CUNNINGHAM, M.P. 1974. A report of the activities of the FAO immunological research on tick-borne cattle diseases and tick control project. *Bull. Off. int. Epiz.*, 81(1-2): 161-166.

FAO. 1975a. *Report of the FAO Expert Consultation on Research on Tick-borne Diseases and their Vectors, Rome, Italy, 6-8 May 1975.* Rome.

FAO. 1975b. *Summary report of the Joint FAO/Industry Task Force on Tick and Tick-borne Disease Control, Rome, Italy, 9 May 1975.* Rome.

MAHONEY, D.F. & ROSS, D.R. 1972. Epizootiological factors in the control of bovine babesiosis. *Aust. Vet. J.*, 48: 292-298.

RIEK, R.F. 1968. Babesiosis. *In* Weinman, D. and M. Ristic. *Infectious blood diseases of man and animals.* II, p. 220-268. New York, Academic Press.

WHARTON, R.H. 1974. Ticks with special emphasis on *Boophilus microplus*. *In* Pal, R. and Wharton, R.H. *Control of arthropods of medical and veterinary importance*, p. 36-52. New York, Plenum Publishing Corporation.

THE MOVEMENT OF LIVE ANIMALS

health aspects of world trade in animals and animal products

by Peter R. Ellis

The veterinary profession is often accused of overstating the risks of disease spread by the international movement of livestock, and is criticized for prescribing what seem to be excessively strict health controls, especially when the disease status of the importing country is less favourable than that of the exporting country. In the current climate fostered by the General Agreement on Tariffs and Trade there is a general desire to simplify and ease restrictions. It is right, therefore, that the nature and extent of health controls should be examined regularly.

Degree of risk

The first question that needs to be asked is whether, in fact, the health risks of stock movement are genuine and significant. Unfortunately, the answer must be an unequivocal "yes," in both respects. Table 1 lists a few of the major epizootics of animal disease resulting from the improperly controlled movement of live animals. Outbreaks where the connexion with suspected sources was denied have not been included in the table, despite the fact that the importing countries had previously been free of the disease and the circumstantial evidence was strong. However, these have all been recorded in the FAO/OIE/WHO Animal Health Yearbooks (e.g., FAO/WHO/OIE, 1975) and in the reports of the European Commission for the Control of Foot-and-mouth Disease (e.g., FAO, 1971).

Other disasters, such as African swine fever which broke out in Cuba in 1971, and swine vesicular disease which appeared in continental Europe in 1972, could also be mentioned, but these outbreaks could not be linked directly to animal movements since animal products were also implicated.

The striking feature of each of these episodes was that a small initial focus led to a disastrous epizootic. It could be argued that the number of episodes was very small in relation to total trade but it must be remembered that in each the impact was concentrated on one or just a few countries. The world as a whole can do little to help when disaster strikes and exporters accept no responsibility for consequential loss. Thus, while the mathematical probability of disaster from uncontrolled livestock imports may be low, the impact on an individual economy can be enormously high. It bears no relationship to the value of the relevant importations and thus cost/benefit calculations are seldom applicable.

Less dramatic problems

An impressive list can also be made of less dramatic problems connected with trade in livestock. Table 2 contains a few of some dozens of recorded instances over the past 20 years.

The disturbing feature of many of these is that they were only traced back to animal importations after the condition had been discovered in domestic stock. Furthermore, some

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This article is based on a paper presented at a symposium entitled Health Aspects of International Trade in Animals and Animal Products, organized by the overseas division of the British Veterinary Association in December 1973.

Cattle from three countries meet at this Nigerian cattle market and railway loading yard

measure of health control had been exercised over many of the related importations, but obviously not enough.

To these examples should be added the disastrous experiences in Ecuador and Chile in the late 1950s, which give a further dimension to the risks involved. At that time importers lost a large proportion of the high-quality breeding stock brought in for development projects due to failure to quarantine them on arrival and protect them against indigenous foot-and-mouth disease. This type of problem continues today. In 1974 12 valuable and treasured Shire horses from the United Kingdom died shortly after their arrival in Nigeria from African horse sickness because vaccine was not available to protect them in good time.

No further evidence should be needed to confirm that the risks of disease are both genuine and highly significant. However, the fundamental nature of the problem deserves comment. At the core is the fact that, over a period of time, each environment or ecosystem develops a pattern of diseases somewhat different from that of all other ecosystems. Differences even arise between herds of the same species in the same general area. Respiration disease in calf-rearing units, and enteric disease in gilts newly introduced to the sow herd, are examples of problems routinely faced by animal husbandmen. There are also plenty of subjective human examples of this regional and local individuality of disease patterns. It is known how diarrhoea develops among families when they move to new communities and how respiratory disease epidemics occur every year among students when they return to university. Such problems arise from differences in microflora at source and destination.

The possibilities of contamination en route complicate the problem still further. For example, rinderpest appeared in Brazil in 1921 with zebu stock from India. Western Australia had an outbreak of rinderpest in 1923 introduced through imported European cattle which had become infected during transport. Libya had a similar experience in 1966 with European stock that had been exposed to African animals at a port quarantine station en route.

Some degree of risk

Then, too, one must accept the clear evidence which exists of the activation of latent infections, such as pasteurellosis and of the *Salmonella* carrier state in cattle, by a relatively calm truck journey. It must be concluded therefore that every animal moved out of its accustomed environment constitutes some degree of risk by virtue of:

— the active diseases which it may take from its source;

— the disease it may acquire en route;
— the latent disease agents or carrier states which may be activated by the journey; and
— the conditions at destination to which it may be especially susceptible.
Obviously these are highly complex and continuing problems.
Defining the areas of risks in this way helps to achieve greater precision in selecting measures which will reduce them to an acceptable minimum. This is possible with a well-planned system of controls and international cooperation, which includes appropriate steps at each stage from source to ultimate incorporation into the national herd of another country.

At source

The importer wishes to be assured that his acquisitions have neither suffered from, nor been exposed to, dangerous infectious disease. This implies that the area of origin must have been free of a specified list of diseases for an agreed period. Various organizations, most active among them being FAO, the International Office of Epizootics (OIE), and the Organisation for Economic Co-operation and Development (OECD), are working toward standardization of such requirements. In a recent publication on non-tariff barriers to international meat trade (FAO, 1973a) are listed, in four categories of importance, 65 diseases which are mentioned in 41 recent bilateral agreements.
Requirements for fresh meat are similar. Some importing countries require the whole country of origin to be free from rinderpest and foot-and-mouth disease for six months or a year, or even longer, before meat from slaughtered animals is acceptable. For less infectious conditions, such as leptospirosis, certification that the farm of origin was free at the time of dispatch is all that is required.
For live animals, the possibility that they may be incubating one of the diseases has also to be taken into account. When sea transport was the only means of overseas shipment, animals were usually aboard long enough to complete the incubation periods and demonstrate infection before arrival. With aircraft now supplanting ships the need for isolation of stock in quarantine stations for up to 30 days before departure has arisen where there is a high risk of infection. Animals destined for immediate slaughter are often exempted from this requirement, but it has become increasingly common for breeding stock.

Table 1

NEW OUTBREAKS OF EPIZOOTIC DISEASE

Year	Area	Disease	Impact
1962	Arabian Gulf	Foot-and-mouth SAT I	Near East to Turkey. Mass vaccination. Buffer zones.
1964-74	Near East	Foot-and-mouth A_{22}	Near East to Turkey. Mass vaccination. Buffer zones.
1969	Arabian Gulf	Rinderpest	Throughout Near East. Vaccination.
1969-72	Central America and Mexico	Venezuelan equine encephalomyelitis	High mortality, animals and humans. Mass vaccination and quarantine.
1972	United States	Exotic Newcastle disease	Eradication (US$50 million).
1973	Turkey and Iran	Foot-and-mouth ASIA I	Local spread. Distant foci. Vaccination.
1973	France	African swine fever	Infected and contact stock destroyed in three departments.
1971	Cuba	African swine fever	More than 500 000 pigs slaughtered in herds at risk; all pigs in affected herds destroyed and incinerated.
1972	Europe	Swine vesicular disease	Slaughter and destruction of affected herds in some countries where eradication was feasible; interference with foot-and-mouth control in others.

All such requirements can easily be written into legislation and regulations, but meticulous compliance is another matter. Authorities in the importing country must have confidence in the disease-reporting system of the exporting country; and also in the capability and integrity of the latter's veterinary service in guaranteeing that health requirements are fulfilled. As the saying goes: "The customer is king." He cannot be forced to take any more risk than he wants. As a result, almost all arrangements are still bilateral in character. Importing countries examine conditions and services in the exporting country; and procedures, tests and certifications have to be agreed before a continuing trade arrangement can take effect.
Other countries may then decide to make importations on the basis of confidence in the judgement of the first importer, but there appears to be no way in which international bodies can take over the responsibility for such health controls. Standard certificates have been agreed upon through OIE, and many countries now use them. Standard tests and criteria for recognizing freedom from disease are also feasible, and steps in this direction started with an FAO/OIE/WHO meeting in Berne in 1964 (FAO, 1964), and further progress has been made through the OIE International Zoo-Sanitary Code (OIE, 1971).

It is in these technical areas that a great deal of progress could be made. Authoritative commentaries on such matters as the relative transmittability of relevant infections, the survival of agents in different types of material, and on the conduct and interpretation of health tests, would be helpful to both importers and exporters. A great deal of useful information is already available in the literature and from specialist committees, but it should be gathered together for easy reference by those concerned with trade in livestock. Constant revision and updating, as well as research on specific topics, would, of course, be essential. An international organization is the obvious body to undertake these tasks. However, the final decision will always depend on the confidence that the importer has in the exporter's capacity to fulfil agreed requirements.

En route

Methods of movement are a vital part of this problem. The new and exciting always springs first to mind, but traditional methods still require most attention. The FAO *Trade yearbook* (FAO, 1973b) records that about 25 million cattle, sheep, goats and pigs entered international trade in 1972. Closer examination of individual country statistics suggests that a very large majority of these must have moved by land for fattening and slaughter. Italy, for example, takes in about 2 million young animals each year, mainly from Central Europe. The United Kingdom normally imports and exports hundreds of thousands of cattle for fattening and slaughter each year, as well as large numbers of sheep, pigs and horses.

Further afield, large numbers of stock are moved in the normal course of traditional production and marketing: southward and westward in west Africa, northward in east Africa and over to the Arabian Gulf. In South America too, substantial numbers of stock move across land frontiers for similar reasons. It is very unlikely that all such movements are recorded, so the total is probably far more than 25 million animals per year.

The greatest source of risk probably arises from this type of trade, which involves the movement of stock for further fattening or immediate slaughter and over which only limited control is exercised. Quarantine stations cannot handle the numbers involved, so alternative control systems must be found. Although much of this movement of stock may not be justified in the light of modern production and processing technology, its very large volume suggests that it will nevertheless continue for many years to come.

Table 2

MINOR DISEASE OUTBREAKS

Year	Country	Disease
1958 1970	Chile Cyprus	Warble fly
1969	Egypt	Contagious bovine pleuropneumonia
1966 1969	South Africa Bulgaria	Scrapie
1971 1972 1973	Peru Israel Colombia	Infectious bovine rhinotracheitis
1973	Greece	Myxomatosis
1972	Uruguay	Equine infectious anaemia

In developing countries, stock route systems like those described by Boldrini and Nabholz in Kenya (FAO, 1971) are the obvious starting points. Animals are moved in a prearranged and orderly manner along fenced tracks from one resting area to another. Watering points and veterinary handling facilities are strategically distributed. The aim is to reduce the risk of contact between groups of stock and with stock in the areas through which they pass.

Not only is the speed of movement being greatly accelerated, but totally new patterns of movement are developing. Completion of a short stretch of the Pan-American Highway between Panama and Colombia will provide the first land link between South and Central America, and open up the possibility of rapid transportation to North America for the first time. The network of new roads in South America across the Amazon basin and over the Andes will radically change trade pattern. Meanwhile, equally significant developments are occurring in Africa.

Guidance is obviously needed on satisfactory health controls for livestock movement in these changing circumstances. Some of the risks of disease spread en route may be eliminated but the danger that animals incubating infections will reach new destinations before showing signs of disease is greatly increased. Resting areas and holding grounds, watering places and inspection facilities will be needed at different locations and on different scales. More effective supervision after arrival must also be envisaged.

Economic expediency

A note of caution is necessary here. In revising systems of transport control, care must be taken to adjust the tendency toward technical perfectionism to meet the needs of economic expediency. New systems must be fairly workable so that traders will not try to circumvent them. It is better to accept a known degree of risk than to encourage clandestine movement, which has been responsible for so much disease spread in the past. Although conditions are dramatically different, a great deal can be learnt from the experiences of the European Economic Community countries over the past ten years in working out freer systems for the interchange of animals.

Reflecting on the immensity of the problem, it may be concluded that if this trade does continue, greater long-term security is more likely to be gained from improvement of the health of animals at source than from inspection and control of mass movements. To this end, countries are beginning to set up "disease-free

Pigs coming ashore at Liverpool, United Kingdom

zones" as a type of large-scale export quarantine station. The title is inaccurate, but the concept of areas which can be kept free of the major diseases significant in international trade is a sound one. Patagonia in Argentina, and the peninsular area in Thailand south of latitude 9°N, are long-standing examples, and the disease-free zone successfully operated in Kenya for beef exports is the result of a recent initiative. These successes have led Tanzania, Ethiopia and the Philippines, among several other countries, to consider the setting up of such zones, and FAO is actively assisting them.[1]

A disease-free zone is a relatively large area with natural barriers, such as the sea, deserts or high mountains, that limit routes of access. Any adjoining areas where livestock are produced are treated as protective buffer areas in which all stock are appropriately vaccinated or treated. Stock destined for the zone are held in the buffer area for several months to ensure that they are generally healthy. The zone itself may be divided up so that production units are suitably isolated, and if any of the diseases concerned should develop it is understood that all export operations cease.

This system has many drawbacks, and is only possible in countries and areas where the essential preconditions exist. Furthermore, it is sub-

[1] Editor's note: The FAO Expert Consultation on Non-Tariff Trade Barriers against Meat and on Disease-free Zones, held in Pendik, Turkey, 22-26 October 1973, recognized that the term "disease-free zones" is, strictly speaking, inaccurate, and recommended that in future the expression "specific disease-free zones" be employed.

Double-decker truck transport for pigs

PHOTOS:
W.T. JACKSON, MRCVS, DVSM

ject to the same constraints of confidence as those which arise with all controls at source. However, the disease-free zone approach is giving considerable impulse to the general intensification of disease control, as well as tending to solve the most urgent export-import control problems.[2]

Modern transportation systems are, of course, equally important for trade in breeding stock. More care is usually given to these animals because of their higher value, and because they are to be mixed as soon as possible with the best stock of the importing country. Because only small numbers are involved they can be dealt with individually, quarantined at the port of departure and subject to all manner of tests and pre-departure treatments. Some experience is now available on procedures, types of equipment, space requirements, watering and feeding. For example, the Council of Europe has promulgated guidelines for transport by rail, Denmark has defined appropriate conditions for transport by ship, and IATA is in the process of making rules about air shipment. Guidelines on other methods of transport undoubtedly exist as well.

Air transport

Air transport represents a whole new set of health and welfare problems. A Boeing 707 jet is reported to carry as many as 800 calves in suitable containers. Success depends upon satisfactory air exchange and temperature control, not only in the air but also on the ground at fuel stops. These requirements limit the carrying capacity of some of the older types of aeroplane. Questions of stress, too, need to be resolved. Tolerances of different types and intensities of sound seem to vary from species to species, and sound insulation may also become a problem.

The protection of animals in transit also requires efficient disinfection of all facilities and vehicles. With swine vesicular disease and foot-and-mouth disease, contaminated vehicles can be a dangerous means of spread. Although much is known about what should be done with buildings, trucks, ships and trains, more needs to be known about disinfecting aeroplanes. The metals, plastics and sensitive instrumentation used in their construction make the risk of damage to them rather high, as some countries have found when they used formaldehyde gas as a disinfectant. On this aspect of the problem it may be concluded that while some fundamental research needs to be done, much of it falls into the category of operational research. This can best be undertaken by assigning recording and even experimental work to stockmen and veterinarians who supervise shipments of animals. Their findings can then be the subject of further investigation to secure definitive solutions.

British cattle arrive in Shanghai by jet aircraft

On arrival

Procedures at ports and frontier posts are fairly straightforward. Veterinary inspection is obviously indicated, and adequate facilities must be provided for the volume of stock involved. Procedures to follow if

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[2] Editor's note: The promotion of animal health can be considerably enhanced, and many of the drawbacks in the system avoided, if the planning and operation of disease-free zone projects are made part of a national plan to eradicate, in successive stages, the diseases concerned from the entire national territory. This approach is used in Argentina and Chile, where the officially certified foot-and-mouth disease-free zones in the south of each of these two countries have been gradually enlarged as eradication has progressed.

the shipment is suffering from disease must be defined. Authority to destroy such animals must be clearly established, and facilities for their destroyal and the safe disposal of carcasses must be available. "Authority" is the key word because, in a number of instances in the past, questions of legal jurisdiction, and dispute over ownership among buyer and seller and insurance broker, have led to dangerous delays. This is particularly serious when animals are simply in transit to another country. Under normal circumstances, animals for slaughter go directly to lairages where they undergo the customary resting period before slaughter. Strict sanitary controls to prevent direct access to or indirect contamination of local stock are needed. It is also important to ensure that no animals are diverted for further fattening or breeding.

Animals for further fattening need more thorough inspection on arrival, as well as protection against local diseases. Ideally, they should be kept in isolation from local stock, with all reasonable precautions taken against indirect spread of disease, for at least 30 days. Thereafter, their movements should be controlled to permit ready identification if disease should subsequently be attributed to their introduction.

A quarantine facility for all animals destined for breeding seems essential, not only for disease control purposes as already outlined, but also to facilitate their adjustment to the new climate into which they may be abruptly placed by air transport. In many instances this period of quarantine, which is usually about 30 days, will be needed to protect the animals from the disease conditions to which they will be exposed when they begin to mix with indigenous animals. As with fattening stock, a period of restricted movement and observation, covering several months beyond the period of initial quarantine, is desirable to limit the impact of unexpected developments.

Conclusions

It must be assumed that international trade in live animals will continue, perhaps not on an increasing scale but certainly with increased complexity. Disease risks are unlikely to diminish, and may change in character due to improved communications. Since little can be done when disasters do occur, importing countries must do all they can to minimize these risks.

Long-term solutions will be found in the more effective control of the relevant diseases in exporting countries. As an interim step the development of so-called disease-free zones is a sound measure. In any event, veterinary services in the exporting countries have to gain and keep the confidence of the importing countries in their capability and integrity.

The health control of the large numbers of animals moved for slaughter or further fattening is the principal problem. Domestic and international stock route systems may continue to operate in some regions, and wider knowledge of their design and operation would be useful. It is also necessary to improve the methods of handling such animals at ports of entry and for monitoring subsequent problems. More needs to be known about welfare and hygiene in the various systems of transport. Operational research and special studies should be encouraged in these fields. Finally, to facilitate the work of importers, exporters and government authorities, a further review of current knowledge of procedures would be helpful. Indeed, the volume of trade in live animals would seem to justify the establishment of a special unit within the United Nations system.

REFERENCES

FAO. 1964. *FAO/OIE/WHO meeting on basic principles for the control of international traffic of animals and animal products.* AN 1964/9.

FAO. 1971. *Report of the eighteenth session of the European Commission for the Control of Foot-and-mouth Disease, 23-26 March.* Rome.

FAO. 1973a. *Non-tariff barriers to international meat trade arising from health requirements.* Rome.

FAO. 1973b. *Trade yearbook, 1972.* Rome.

FAO/WHO/OIE. 1975. *Animal health yearbook, 1974.* Rome, FAO.

OIE. 1971. *International zoo-sanitary code.* Office International des Epizooties, 12, rue de Prony, Paris (17e).

the next issue

will include articles on the following subjects

Vampire bats and their effect on cattle production in Latin America

Turkey production

Veterinary training for the tropics

Recent advances in pasture development in the Peruvian tropics

Tick-borne livestock diseases and their vectors. 2. Epizootiology of tick-borne diseases

New facets of animal breeding research in the United States

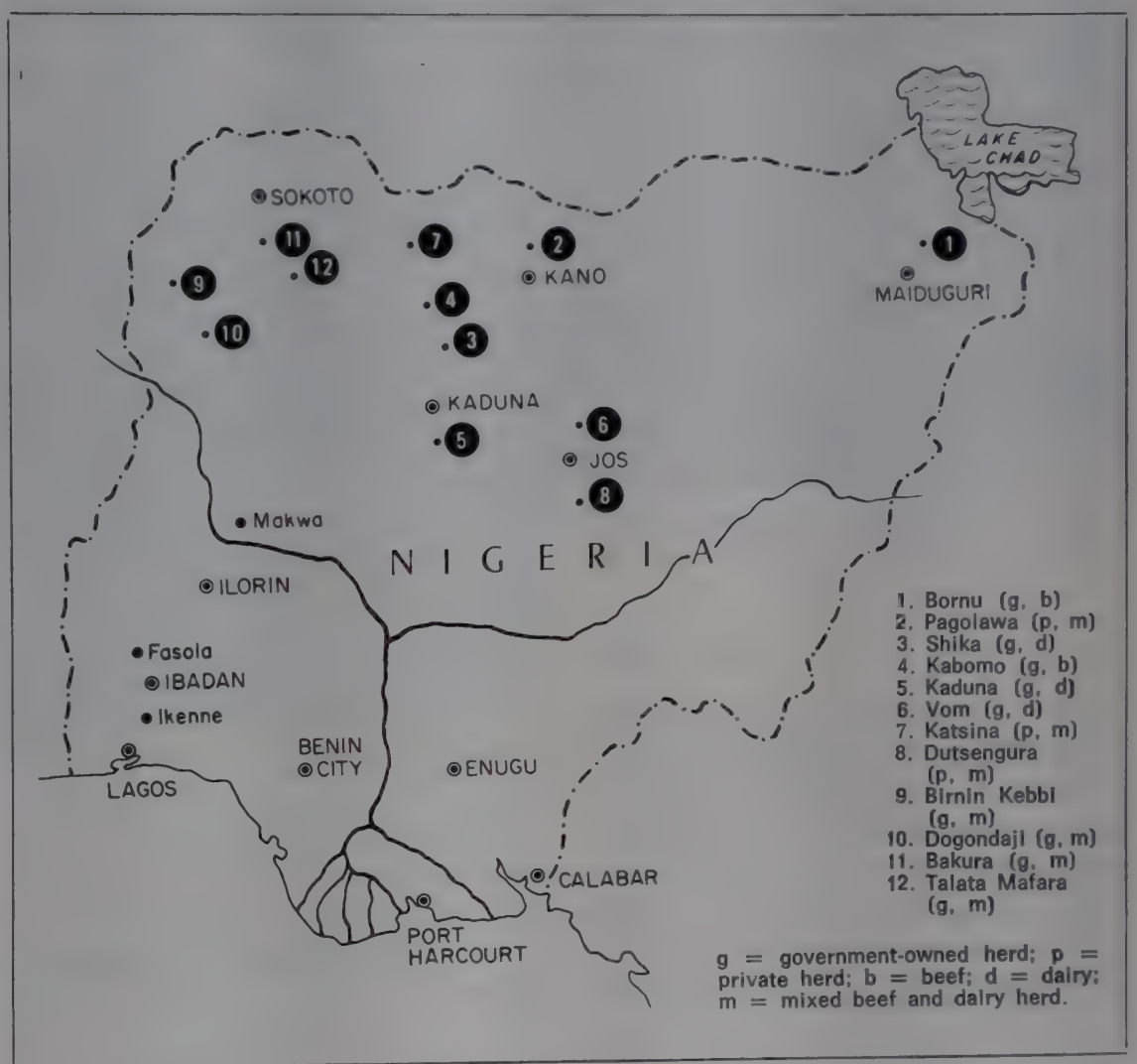
Lessons from a survey of successful experiences in assisting the smallholder livestock producer

Bovine cutaneous streptothricosis in Nigeria

by O.O. Oduye

Although first described as "dermatose contagieuse" of cattle in the Belgian Congo (Van Saceghem, 1915), cutaneous streptothricosis caused by *Dermatophilus congolensis* is a worldwide disease which affects a wide range of domestic and wild animals. The disease has been reported in cattle in Australia, the United States and the United Kingdom. In Africa the disease in cattle is also known by a variety of other names, such as contagious impetigo, senkobo skin disease, saria, dro-dro boka and kirchi.

D. congolensis is the cause of mycotic dermatitis or lumpy wool disease of sheep in Argentina, Uruguay, South Africa, Australia and the United Kingdom. It is also the causal agent of "strawberry foot rot," a proliferative dermatitis of the lower leg, in sheep in Scotland. Natural infections by *D. congolensis* in horses have been reported in Australia, Kenya, Nigeria, Zambia, the United Kingdom and the Netherlands. Dermatophilus infection also occurs in goats and pigs, and in wildlife, including deer, gazelle, giraffe and zebra, donkeys, cottontail rabbits and lizards. The disease has been reported in man as well (Kaplan, 1973).



Map of Nigeria showing streptothricosis study areas. Surveys were carried out in the numbered areas only.

Clinical appearance and distribution of lesions

The disease in cattle is a chronic dermatitis which becomes perceptible when the hair of an affected area of skin becomes matted with a thick exudate, which hardens when dry and is often held in place by tufts of hair presenting a paintbrush appearance. The lesions appear as tiny scabs (Figure 1) or irregularly outlined areas of scabs formed by the coalescence of several tiny scabs (Figure 2). Although the lesions can occur in any part of the body and occasionally become generalized, they are usually distributed along the back of cattle in northern Nigeria, particularly in the lumbar region and behind the withers in the hump area (Figure 3). In the southern forest zone of the

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Figure 1. Generalized streptothricosis in a Friesian cow. Note tiny and discrete scabs scattered all over the body.

country, the lesions are concentrated in the animals' extremities, including the lower limbs (Figure 4), and the muzzle and tail (Figure 5). Lesions which affect areas of tick attachment, such as the axilla or groin (Figure 6), are found in cattle in both the northern and southern regions of Nigeria.

Incidence

The extent to which the disease occurs in cattle varies considerably in different parts of Africa. Incidence figures of 41 percent in Madagascar and up to 80 percent in Rwanda have been reported, but there is no information on the total number of animals on which these figures are based. A definite seasonal variation in the incidence of the disease has been reported in Ghana, with infection rates of 5 and 13 percent during the dry and wet seasons respectively.
In Nigeria, there is considerable variation in the data from surveys. Out of a total of 87 050 cows examined in September 1968 in northern Nigeria, 10.5 percent were reported infected (Oduye and Lloyd, 1971). In a further survey of 1 785 cattle (Kelley and Bida, 1970), the incidence was 12 percent. The table gives the results of a survey carried out between September 1968 and August 1970 covering a large area of the northern states of Nigeria. Despite variations in the available reports, it may be estimated that 10 percent of the total cattle population of Nigeria is infected. It is significant that the disease does not assume the same

INCIDENCE OF BOVINE STREPTOTHRICOSIS IN NIGERIA

Period of survey	No. of animals examined	No. with skin diseases	No. with streptothricosis
October-November 1968 [1]	3 439	254 (7.4%)	212 (6.2%)
February 1969	3 574	237 (6.6%)	157 (4.4%)
October-November 1969 [1]	3 753	348 (9.3%)	209 (5.6%)
February-March 1970	3 804	184 (4.8%)	70 (1.8%)
July-August 1970 [1]	3 670	324 (8.8%)	162 (4.5%)

[1] Wet season

dimensions in east Africa; indeed, it has been reported to be very rare in Uganda.

Figure 3. Note distribution of lesions along the back of this bull.

Figure 2. Generalized streptothricosis in a White Fulani cow. In this case the lesions have coalesced to form irregular patches of scabs.

Economic importance

Although bovine streptothricosis has been regarded in Nigeria as the second most important bacterial disease of cattle after bovine contagious pleuropneumonia, the economic losses to the nation caused by this disease have not been fully investigated and are difficult to determine. Losses are incurred in the death and culling of severely affected animals, in the damaging effect of the disease on hides, and the progressive emaciation of affected cattle.

Losses due to death and culling

Records from some survey centres in Nigeria show that about 2 percent of diseased animals die annually, while about 4 percent in many herds are culled due to cutaneous streptothricosis. If the cattle population of Nigeria is accepted as 11 million (FAO, 1973) and 10 percent of these are infected, it means that every year about 22 000 animals are lost, while another 44 000 are culled. Diseased animals usually fetch no more than half the normal market price.

Losses due to infected hides

The most easily recognized economic loss caused by bovine streptothricosis is damage to hides and skins. These have three important markets in Nigeria: they are eaten as a delicacy; they are used for the local production of leather goods; and they are exported.

Diseased skins are rejected, and also they cannot be used for food. Affected hides are rejected for export purposes, and it is only in the manufacture of local goods that these hides find a use. However, they are considerably downgraded because of the blemishes which appear as unsightly grain cracks in the affected areas.

It is difficult to make precise estimates of the economic loss to the hides and skins industry caused by the disease. This is because few slaughterhouses in the country keep records of affected and rejected skins. According to Lloyd (1973), about 168 000 hides are spoiled annually.

Other losses

When the limbs of cattle infected by *D. congolensis* are affected, the animals are unable and unwilling to move because of pain, and therefore they are unable to feed well. This leads to progressive weight loss and, in dairy cattle, to a marked reduction in milk yield. In beef cattle, this also causes reduced growth rate in suckling calves. Draught cattle affected by streptothricosis constitute a further loss to the mixed farmer. These miscellaneous losses are difficult to quantify in the present state of our knowledge of the disease.

Treatment and control

Successful treatments of infected cattle by the removal of scabs followed by topical application of medicaments such as carbolic acid, a mixture of picric acid and copper sulphate solution, phenol solution, linseed oil, quaternary ammonium compounds and sulphur ointment have been

reported. In our experience removal of scabs followed by topical application of Aureomycin spray and/or sulphur ointment in groundnut oil has proved effective. Successful treatment in such cases, however, implies that the infection is already overcome by the partial or complete detachment of scabs. This method is very time consuming and impractical in severe cases or when many animals in the same herd are affected.

Intravenous injection of sodium iodine was useful in healing mild infections in Australia, but was of no value in generalized cases. The same treatment and/or oral administration of potassium iodide have been found to be beneficial in Nigeria.

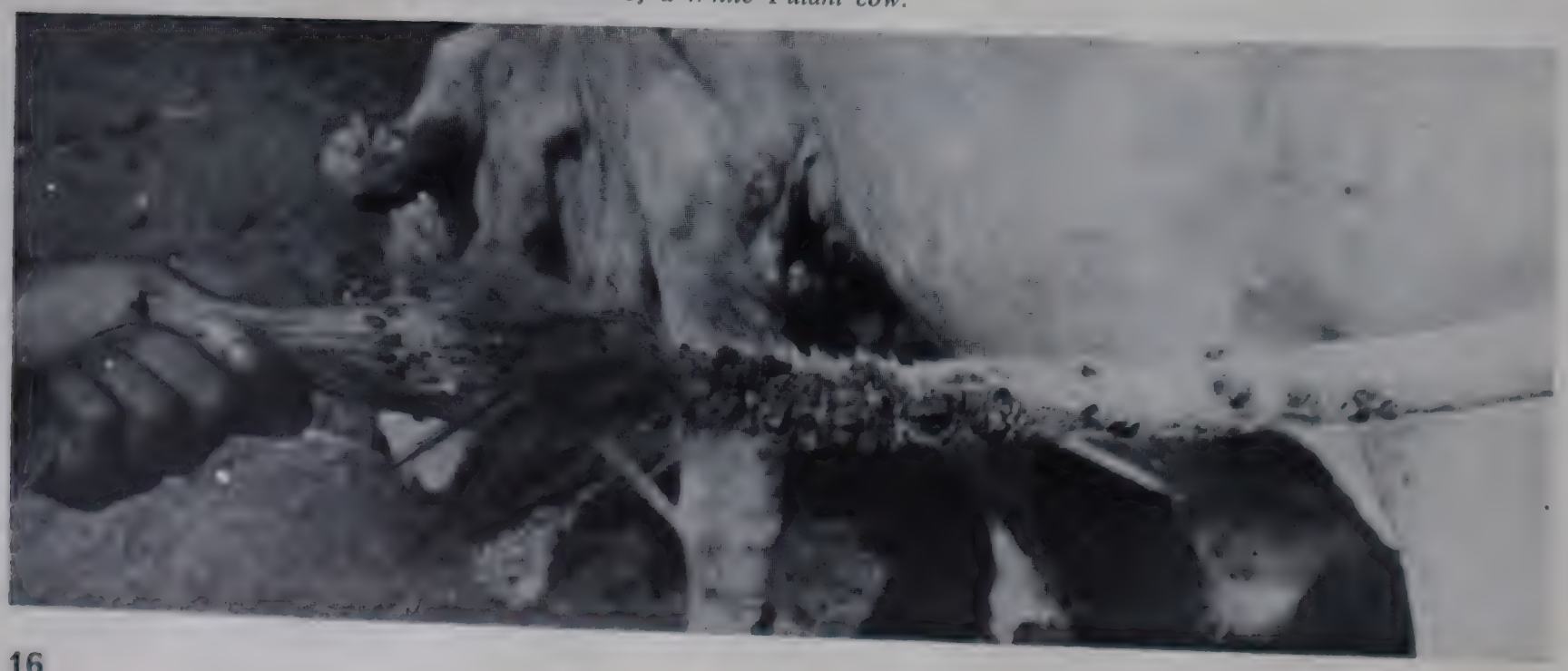
Figure 4. Thick and confluent scabs on all four limbs of a White Fulani cow.

Antibiotics

Although *D. congolensis* shows remarkable sensitivity to many antibiotics *in vitro* (Plowright, 1958), the effects of these agents *in vivo* have been disappointing. Intramuscular administration of penicillin at a dose rate of 5 000 units/kg of body weight for five consecutive days, or one injection of 75 000 units/kg, has been reported satisfactory. In our experience, however, parenteral administration of heavy doses of penicillin with or without streptomycin has proved effective only in a limited number of cases. Recovery was often followed by recurrence of the disease within two months of treatment. When this happened, further antibiotic treatment had no effect on the disease. Apart from the relative ineffectiveness of parenteral administration of antibiotics, the cost involved is very high and may not be justified except perhaps in the case of imported stock.

The environmental factors associated with natural outbreaks of bovine streptothricosis are rainfall and the trauma of bovine skin caused by insect or tick bites, pecker birds (*Boophagus africanus africanus*), tree branches and thorny bushes. It has been shown that trauma of the bovine skin is the main factor for the establishment of experimental bovine streptothricosis using culture of *D. congolensis* (Oduye, 1975). The dis-

Figure 5. Hard, dry, thick horny scabs on the tail of a White Fulani cow.



ease is observed to develop more rapidly with the onset of rainy periods, which also coincide with maximum tick and insect activity. The implication of ticks and flies in the transmission of *D. congolensis* suggests that effective tick and insect control should help control cutaneous streptothricosis. Indeed, Plowright (1956) demonstrated that dipping of cattle (in benzene hexachloride solution) at regular intervals to control ticks reduced the incidence of the disease. In Nigeria, regular tick control in government herds has lowered the incidence of streptothricosis.

Figure 6. Groin of bull showing scabs of streptothricosis lesions. Note also involvement of the scrotum.

If this practice could be extended to the local Fulani herds, the disease may be expected to decline.

Immunity and vaccination

Some local breeds of cattle in Africa — the Muturu, the N'dama and the Baole — are resistant to natural infection by *D. congolensis.* Chad Brahma and Arab zebu are recurrently infected without showing any evidence of protective immunity. Naturally infected animals have been found to develop antibodies against *D. congolensis* (Perreau and Chambron, 1966; Oduye, 1974). Demonstration of circulating antibodies could be very useful in diagnosing the existence of infection in a herd.

Although vaccinated as well as experimentally infected cattle develop circulating antibodies, these antibodies do not protect the animals against natural infection (Perreau and Chambron, 1966; Pulliam *et al.*, 1967). It is difficult to explain the unprotective nature of the circulating antibodies, since several strains of *D. congolensis* obtained from various sources are antigenically and serologically homogeneous. A very early response in re-infected rabbits has been demonstrated and attributed to "delayed hypersensitivity reaction." It is possible that repeatedly infected cattle suffer from a delayed type of hypersensitivity reaction. Further work is required to elucidate this point. Provost *et al.* (1974) have claimed the protection of zebu cattle in southern Chad against natural dermatophilosis following intradermal inoculation of a young culture of *D. congolensis.*

With our present state of knowledge of this disease in cattle in Africa, the search for an effective cure and adequate control measures continues.

REFERENCES

FAO. 1973. *Production yearbook 1972.* Rome.

Kaplan, W. 1973. Dermatophilosis in primates. *Proceedings of the International Symposium on Dermatophilus Infection, Ibadan, Nigeria, 1973,* p. 62-71.

Kelley, D.C. & Bida, S.A. 1970. Epidemiological survey of Streptothricosis (Kirchi) in Northern Nigeria. *Bull. epizoot. Dis. Afr.,* 18: 325-328.

Lloyd, D.H. 1973. The economic effects of bovine streptothricosis. *Proceedings of the International Symposium on Dermatophilus Infection, Ibadan, Nigeria, 1973,* p. 111-112.

Oduye, O.O. 1974. A comparative serological study of *Dermatophilus congolensis* antigens prepared by different methods. *Br. vet. J.,* 130: lix-lxii.

Oduye, O.O. 1975. Effects of various induced local environmental conditions and histopathological studies in experimental *Dermatophilus congolensis* infection on the bovine skin. *Res. vet. Sci.* (In press)

Oduye, O.O. & Lloyd, D.H. 1971. Incidence of bovine cutaneous streptothricosis in Nigeria. *Br. vet. J.,* 127: 505-510.

Perreau, P. & Chambron, J. 1966. Immunologie de la streptothricose cutanée des bovins. Essai de vaccination. *Rev. Elev. Méd. vét. Pays. trop.,* 19: 263-275.

Plowright, W. 1956. Cutaneous streptothricosis of cattle: I. Introduction and epizootiologic features in Nigeria. *Vet. Rec.,* 68: 350-355.

Plowright, W. 1958. Cutaneous streptothricosis of cattle in Nigeria. II. The aerobic actinomycete (Nocardia sp.) associated with the lesions. *J. comp. path.,* 68: 133-147.

Provost, A., Toude, M.P., Guillaume, Peleton, H. & Damsou, F. 1974. Vaccination tests against bovine dermatophilosis in the southern region of Chad. *Bull. epizoot. dis. Afr.,* 22: 223-229.

Pulliam, J.D., Kelly, D.C. & Coles, E.H. 1967. Immunological studies of natural and experimental cutaneous streptothricosis in cattle. *Am. J. vet. Res.,* 28: 447-455.

Van Saceghem, R. 1915. Dermatose contagieuse (Impetigo contagieux). *Bull. agric. Congo Belge,* 8: 354-359.

Energy
and Australian agriculture

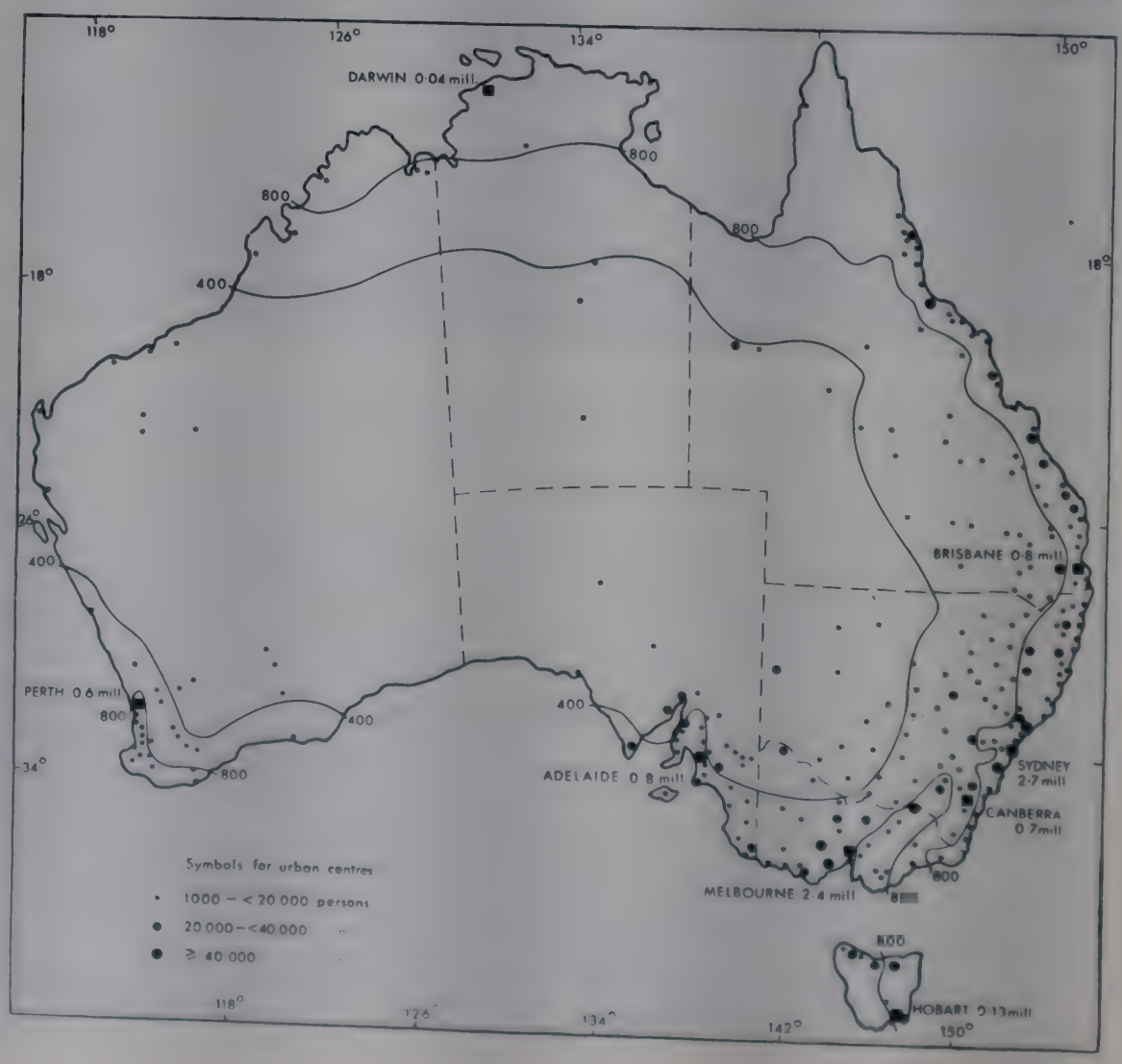
by R.J. Millington

The growing world population has led to a revival of the Malthusian debate on the ability of man to ensure the continuing supply of resources to meet increasing demands. In this debate the significance of energy, food, land, water and mineral resources is assessed in two ways. An initial assessment is made of the ultimate quantity, mass or area which is available and which constitutes our resource capital; a second assessment is made of the actual or predicted rates of consumption of the resource. From the size of the resource and its rate of depletion, estimates of the longevity of the supply are made.

Some resources are deemed renewable, and it is assumed that the annual harvest takes the form of interest on nondepreciating resource capital. With solar energy and rainfall this assumption can be justifiable. However, with food-producing systems it is only true when the rate of removal of harvest products is commensurate with the rate of replacement of components of the system, either by release from "infinite" soil reserves or by their additional application. Maintenance of physical or structural characteristics of the system is also assumed.

Soil reserves are not infinite. At any site, the reserves of each nutrient are determined not only by the absolute abundance of the particular nutrient but by the extent to which plant root systems can penetrate and explore the soil beneath. The depth of soils is finite, the concentrations of nutrients are finite, rates of release are

Figure 1. Population distribution in Australia (June 1971), and median annual rainfall (isohyets in mm).



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This article is based largely on an earlier publication on energetics of agriculture and food production, with special emphasis on the Australian situation (Gifford and Millington, 1973)

finite, and the temporal pattern of both plant demand and root size and activity are finite.

The productivity of agricultural land is dependent on all the inputs to the system. High productivity, in terms of yield per unit area, can be maintained only by continuing these inputs, some of which are nonrenewable resources, including materials and energy currently derived from fossil fuels.

Examination of the energetics of agricultural systems is directed primarily toward providing a better understanding of the most basic part of the web of interlocking activities which comprises human ecology. Food and water are human needs on a daily cycle. We rely primarily on annual plants whose production cycle is measured in intervals of a hundred days or so and on the soils in which these plants grow, which have developed over centuries or millennia but can be degraded, in the absence of appropriate husbandry, in decades.

The current emphasis on energy in relation to food and population is appropriate since there is now no doubt that natural liquid petroleum fuels will be exhausted and that limited coal reserves, fission reactors and yet to be developed operational breeder reactors all present problems. Food must be produced and distributed continuously, and if energy supplies are reduced the impact on food production and consumption will be essentially immediate. The lead time for contingency planning of food supplies is the same as that for energy supplies.

Figure 2. Wheat areas

Figure 3. Sheep areas

Figure 4. Beef cattle areas

Distribution of population and agriculture in Australia

Australia's population of 12.7 million (1971 census) is concentrated in the major urban areas, which account for 8.2 million people or 64.6 percent of the total population. Other urban areas which constitute the service centres for Australia's rural communities include 2.7 million or a further 21.1 percent of the continent's total population. The remaining 1.8 million people are rural dwellers, i.e., they live on farms and in villages or hamlets with populations of less than 1 000. The geographical distribution of Australia's population is even more unbalanced, for over 90 percent of the people live south of latitude 27°S, i.e., south of the city of Brisbane.

Ignoring the populations of the capital cities and the large industrial and mining centres which are located along the coast, population density in southern Australia broadly approximates the pattern of mean annual rainfall (Figure 1).

To the north of Brisbane the total population is approximately only 1.2 million, and over 90 percent of these people live in coastal cities. Rural population densities are correspondingly lower in areas between the 500 mm and 750 mm isohyets, and rural population densities in northern Australia are between 0 and 0.5 person/sq km compared with 1.5-3.0 person/sq km in southern Australia. These northern/southern variations in Australia's rural population densities are associated with variation in primary productivity, as illustrated in the distribution of wheat, sheep and beef cattle in Figures 2, 3 and 4.

Energy inputs for Australian agriculture

The sources of energy input for agriculture include petroleum products, coal, natural gas, electricity, wood and manpower. The kinds of sink into which energy flows include fertilizer manufacture, cultural operations, transportation, machinery manufacture, maintenance of the farm infrastructure and so on. From the farm gate, transportation, processing and marketing add further energy costs prior to local consumption of the primary farm products as well as the overseas export of farm products and processed foodstuffs.

In Table 1 are given the component energy inputs to the farm gate, from the farm gate to the retail store or export outlet, and from those outlets to human consumption either in Australia or its export markets. These data include estimates of the energy inputs required to produce all Australia's farm and food products, including the export component. The estimate of 50×10^{15}J per annum for export transportation is an underestimate in that it covers only the

Australian bunkering of primary product trading vessels which probably refuelled en route to their destination.[1]

The local consumption expresses fulfilment of the food requirements of 13×10^6 people, and constitutes about 30-40 percent of the total foodstuffs produced. Assuming that the foodstuffs exported are used on a per caput basis similar to Australian consumption, then the exports feed another $25\text{-}30 \times 10^6$ people. In the process, assuming similar social organization and geographic distribution, another 200×10^{15}J would be required for transport, refrigeration and cooking of the export component after arrival at its port of destination overseas.

To place food on the tables of 13×10^6 people locally requires an energy expenditure of about 250×10^{15}J per annum. Only about 12 percent of the energy expended is in production as far as the farm gate; the other 88 percent is expended in processing, distribution, storage and cooking. On a per caput basis the energy expenditure to the dining table is 18×10^9J per annum, whereas the estimated food supplied per caput prior to kitchen cooking and other losses is about 3 000 kcal per day or 4×10^9J per caput per annum.

When food is exported by sea the energy cost is $150\text{-}850 \times 10^3$J per ton-km of freight. With destinations in further parts of the northern hemisphere (15 000 km) the additional transportation energy expended would amount to $1\text{-}5 \times 10^9$J per caput per annum where overseas consumers require 250 kg of foodstuffs per caput per annum.

For many of the developing countries the importation of foodstuffs incurs energy expenditure in sea transportation which, on a per caput basis, is comparable with the total energy expenditure per caput in the importing country. It is clear that energy expenditure in transportation of foodstuffs within Australia is comparable with the total energy inputs expended in production to the farm gate.

[1] J = joule (4.18 joules = 1 kcal).

Output of Australian agriculture

Extending from latitudes 10° to 40°S and across 40 degrees of longitude, Australia embraces dry and wet tropical climates, vast areas of arid interior similar to other countries of middle latitudes and low relief, and in the south mild Mediterranean climates. The country has extensive areas suited only to low input (and low output) pastoral activity and adjacent belts where small and coarse grains are produced by rainfed agriculture. Relatively small areas in higher rainfall regions produce sugar in the north, and horticultural and dairy products in the south. Rainfall variability over the continent is high. Figure 5 summarizes the output of Australian agriculture, including the derived animal products.

Table 1

Annual energy inputs in Australian agriculture and farm products (1965-69 averages)

	For locally consumed products	For export products
	× 10^{15}J per annum	
To the farm gate [1]		
Primary fuel	14	32
Electricity	2	6
Fertilizer, mining, transportation and manufacture	7	12
Agricultural chemicals	2	3
Farm machinery manufacture	2	5
Transportation	1	1
Farm labour	1	1
From farm gate to retailer (or exporter)		
Transport	15	15
Processing	56	[2] —
Packaging	29	[2] —
Retail to local consumer		
Transport	33	(say) [3] 50
Refrigeration	46	—
Cooking	42	
Total	250	125

[1] From estimates of total energy inputs, the partitioning of energy inputs to export and local consumption have been based on relative mass and energy contents of locally consumed and exported foodstuffs. — [2] The export component of packaging and processing is small and has been neglected. — [3] Ships' bunkers.

The estimated $2\,400 \times 10^{15}$J of animal feed consumed include pasture, harvested hay and grains. The resulting total edible animal products are equivalent to 43×10^{15}J. The estimate of pasture consumed is based on estimated daily intake of feed by both sheep and cattle and on data on Australian sheep and cattle populations. Sheep intake was calculated as 1 kg dry matter per head per day and for cattle 10 kg dry matter per head per day.

The apparent efficiency of conversion of feed to edible animal products is low. Two contributory factors to this apparent low conversion in Australia are, firstly, the low quality of natural pastures, and secondly, the number of sheep raised for wool and not for meat production. In the inner pastoral area of Australia, which holds about a quarter of the total livestock population of the country, the animals derive their feed from natural plant communities covering more than 300×10^6 hectares. Land which has been improved by ploughing, fertilizer application or the introduction of improved pasture plants is currently about 50×10^6 hectares, and estimates of the further dryland agricultural expansion suggest that another 20 to 30×10^6 hectares might be developed.

Comparative energy use

Total agricultural production, distribution, food processing (including domestic storage and cooking) and exports require inputs totalling 375×10^{15}J per annum compared with a total primary energy consumption for the country of about $2\,000 \times 10^{15}$J per annum. If the export component is ignored, then to the farm gate the energy input is about 2 percent of the total national energy use, and to process, distribute and put food on the dining table a further 10 percent of the national energy use is required. Steinhart and Steinhart (1974) arrive at similar estimates for the United States, where the inputs

to the farm gate are about 3 percent and processing, distribution and cooking another 10 percent of the total national energy consumption.

In Table 2 data derived from Gifford and Millington (1973), Steinhart and Steinhart (1974), Blaxter (1974) and Stanhill (1974) afford a comparison of some features of energy inputs into four diverse patterns of agriculture. The diet of all four countries is similar in terms of calorie and animal protein intake. It is clear that the data support the contention of Slesser (1973) that increasing agricultural inputs per head are required as the area exploited per head decreases, and this result is not unexpected.

However, there are differences in the pattern of inputs, Israel putting in a large energy component as irrigation and the United Kingdom a large component as fertilizer. Australia, with largely dryland agriculture, is the continent with the lowest rainfall and runoff and highest variability in rainfall, and proceeds with generally low input forms of food production. This is dictated by the fragility of its landscapes and the water-limited response to applied nutrients.

Both the United Kingdom and Israel support a similar proportion of their respective populations on locally produced foodstuffs. The energy inputs to the farm gate in the United Kingdom constitute about 7 percent of the total energy use in the country and in Israel some 11 percent. It is quite clear that both countries can further increase yield per unit area of agricultural land and effect some expansion in the area devoted to agriculture, and in so doing incur increasing energy costs in the feeding of their growing populations.

Increase in productivity per unit area and the area utilized are both limited, and clearly there are also limits beyond which further increments of energy-demanding inputs result in no further increment in output. The kinds of policies needed to cope with food, energy and population will continue to exercise decision-makers in both developed and developing countries, but with differences in emphasis.

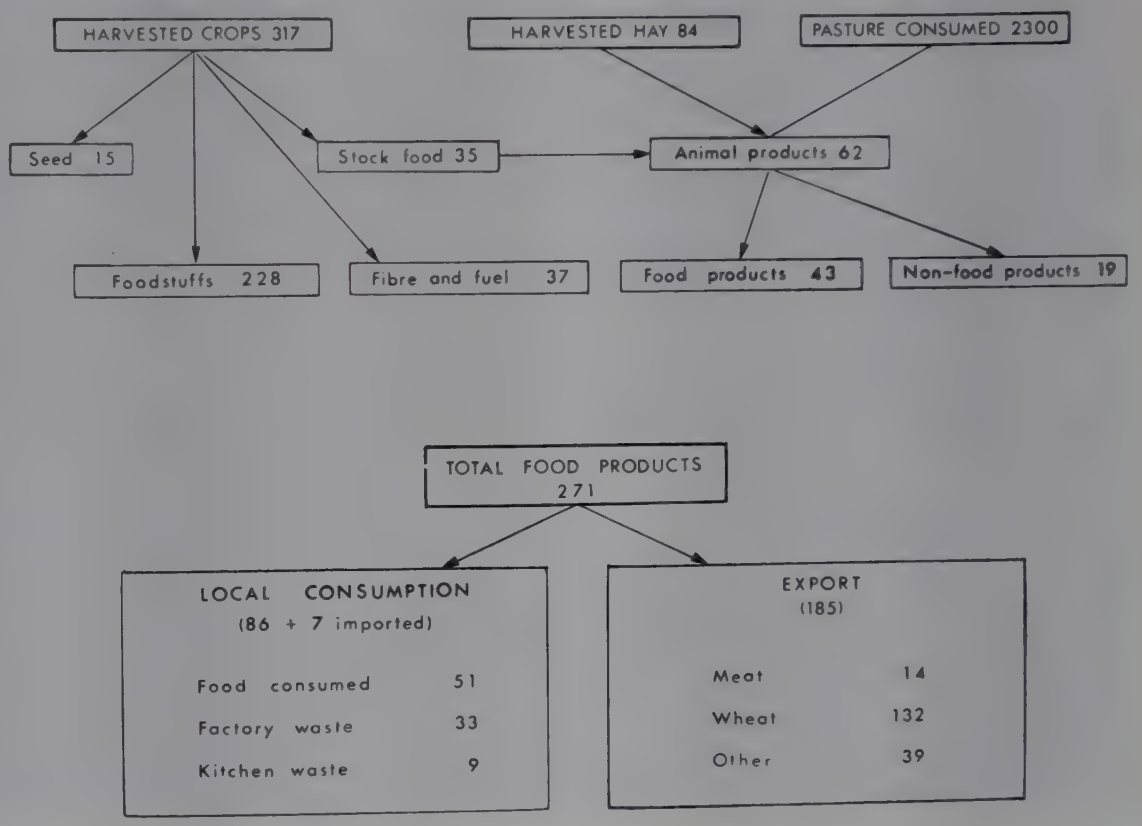
Fertilizers and intensification of agriculture

The low inputs of fertilizers in Australian agriculture are primarily due to the dual effects of low rainfall and high rainfall variability. This can be illustrated by the following examples of production trends which have resulted from increased inputs. Over the 30-year period 1940-70 yields of apples, pears, oranges and peaches per unit area have more than doubled. These crops are characteristic of the higher rainfall areas of Australia or are grown under irrigation. Potatoes and sugar, crops of higher rainfall areas and with some irrigation, have also shown at least a doubling in yield per unit area. Most of the nitrogen fertilizer inputs in the country are used in sugar production, and that used for horticultural crops is second in significance.

With wheat, however, which is almost all produced from rain-fed dryland agriculture, there has been only a trend, according to Russel (1973), for yield per unit area to increase by 1-2 percent per annum. Although his polynomial analysis shows that the linear trends with time are significant, the variance accounted for is only 20-30 percent of the total variance. The variance accounted for rises to only 30-40 percent with the fifth degree polynomial. When one looks at the data for wheat yields from Victoria and New South Wales over the 25-year period 1945-70, there is no discernible increase either in average yields or in the yields of the highest yielding crops in these states. Although Russel's analysis described trends with statistical precision, the fact is that the standard error is about 30 percent of the regression coefficient, and yield variability is so high that statistical analysis is necessary to detect any increase in yields with time.

The bulk of Australia's fertilizer use is in the application of phosphatic fertilizers to soils derived from predominantly sedimentary rocks. Of the phosphate used, two thirds is applied to pastures. The phosphate status of Australian soils is low and the current input to produce food to feed 40×10^6 people at the Australian level of consumption is 3.3×10^6 tons of superphosphate per an-

Figure 5. Output of Australian agriculture in energy terms. Upper part of figure relates to products at the farm gate, and lower part to the fate of these farm products as food for local and export consumption [1] (units are 10^{15}J per annum).



1 Fibre and fuel includes 35×10^{15}J cane bagasse used as sugar mill fuel.

num. This is equivalent to an input of about 9 kg of phosphate per caput fed whereas the human intake is about 0.5 kg per head per annum.
Australia's livestock and wheat industries dominate the country's production of total protein, and these industries have developed in the absence of significant inputs of energy-demanding nitrogenous fertilizers. The relatively low productivity of the industries in terms of protein yield per unit area is a reflection of two limiting factors, water and nitrogen.

Enhancing energy-demanding inputs

Maintenance of nitrogen status and its improvement compared with indigenous plant communities have been achieved in higher rainfall areas primarily through incorporation of pasture legumes, and this method is relatively cost-free in energy terms. However, the rates of production of nitrogen through legume fixation, and its rate of release per unit volume of the upper layers of the soil, are the rates characteristic of biological and microbiological systems. Both the synthetic and mineralizing systems as well as the volatilization process are dependent on chemical and physical characteristics of the soil and of the aerial environment. Just as water may limit the productivity of cereal crops and nonlegume pasture plants, it can similarly limit fixation, mineralization and gaseous loss of nitrogen.
It is clear that intensification of production might be accomplished by enhancing energy-demanding inputs, and this intensified system will require not only the initial money or capital investment in irrigation storage and water distribution works and in fertilizer plants, but recurrent costs in money and in energy inputs. The stability of such enhanced production systems demands continuing energy inputs.
Dryland under agriculture (as distinct from the unimproved semiarid pastoral zones) might extend from the present 50×10^6 hectares to $70\text{-}80 \times 10^6$ hectares, and the potentially irrigable land to about 5×10^6 from the present 1.6×10^6 hectares. Allowing a further doubling of productivity on high rainfall land and on present and future irrigated land, it has been estimated that total food production could be increased by 50 percent (Gifford *et al.*, 1975). Such increases in food production will result in higher energy inputs to the farm gate, but even the doubling or tripling of this component is of small consequence in the total energy budget of the country or compared with the additional energy inputs required for transport, processing, storage and cooking of food.
On an international scale the objective of regional self-sufficiency in foodstuffs is being pursued where it is yet possible. However, not only in less developed countries, but also in the developed countries of Europe this goal may no longer be attainable, and energy expenditure in overseas transport will continue to grow. Internally, in any nation or region, the balance in population distribution between remote hinterlands and urban agglomerations leads to similar considerations of self-sufficiency, but at a different geographic scale.
In a now energy-conscious world the value of the food calorie and the joule are subject neither to inflation nor to fluctuations in exchange rates, and we have at our disposal an even more pervasive medium than money through which to approach human ecologic problems.

Table 2

Energy, agricultural area and population characteristics of Australia, United States, United Kingdom and Israel

			Australia	U.S.A.	U.K.	Israel
a	Energy input to farm gate	$\times 10^{15}$J	29	2 209	346	[1] 20
b	Energy input to fertilizers (including transportation)	$\times 10^{15}$J	6	400	128	2.1
c	Primary fuel used on farm	$\times 10^{15}$J	14	232	144	3.2
d	Population fed	$\times 10^6$	13	[2] 200	[3] 30	[4] 1
	Agricultural land per caput	*hectares*	[5] 2.3	0.76	0.27	0.04
a/d	Energy input to farm gate per caput per annum	$\times 10^9$J	2	11	11	20
b/d	Fertilizer energy per caput per annum	$\times 10^9$J	0.5	2.0	4.3	2.1
c/d	Primary fuel per caput per annum	$\times 10^9$J	1.0	4.9	4.8	3.2

[1] Includes equivalent of 13×10^{15}J for pumping irrigation but excludes about the same energy equivalent of imported animal feed. — [2] Food exports have been ignored. — [3] Local production supported 60 percent of the population. — [4] Local production supported 58 percent of the population and balance was imported. — [5] About 20-30 hectares of arid pastoral zone holdings are included.

REFERENCES

BLAXTER, K.L. 1974. Energy in agriculture, N.R. McFarlane. *Nature*, 252: 551.

GIFFORD, R.M., KALMA, J.D., ASTON, A.R. & MILLINGTON, R.J. 1975. Biophysical constraints in Australian food production: implications for population policy. *Search (Syd.)*, 6: 212.

GIFFORD, R.M. & MILLINGTON, R.J. 1973. *Energetics of agriculture and food production with special emphasis on the Australian situation*. Melbourne, Commonwealth Scientific and Industrial Research Organization. Bulletin No. 288.

RUSSEL, J.S. 1973. Yield trends of different crops in different areas and reflections on the sources of crop yield improvement in the Australian environment. *J. Aust. Inst. Agric. Sci.*, 39: 156.

SLESSER, M. 1973. How many can we feed? *Ecologist*, 3: 216.

STANHILL, G. 1974. Energy and agriculture: a national case study. *Agro-Ecosystems*, 1: 205.

STEINHART, J.S. & STEINHART, C.E. 1974. Energy use in the U.S. food system. *Science*, 184: 307.

Game domestication for animal production in Africa

PHOTO: TOMASYAN

Nomadic eland, goats and cattle entering portable pens at dusk

Experiences at the Galana ranch

by J.M. King and B.R. Heath

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Bushmeat is an important source of animal protein in some African countries. On marginal land the conservation and cropping of game animals can be more profitable than cattle ranching (Dasmann and Mossman, 1961). But game ranching has only been developed on a significant scale south of the Zambesi; elsewhere, game tend to be harvested in an indiscriminate and wasteful manner.

The application of game ranching techniques to the abundant wildlife of central and eastern Africa has met with limited success. The numerous cropping projects have been

designed primarily to conserve the habitat or decrease grazing competition of game animals with livestock. Very few operations have been conceived on a sustained yield basis; none have made a continuing contribution to meat production, most of them being content to make a small profit from skins and trophies.

Above: Adult oryx is chased with vehicle and caught by hand (photo by Tomasyan)

Above centre: Newly captured oryx in grass-padded cell (photo by Tomasyan)

Right: Domestic oryx with Masai herdsman (photo by Tomasyan)

Above right: Meat inspection of oryx slaughtered at conventional livestock abattoir (photo by King)

Critical factor

The critical factor in game ranching appears to be the cost of harvesting and marketing fresh meat, especially where veterinary and public health requirements are strictly enforced and distances to market are long. The local demand for highly priced chilled or frozen venison appears to be limited. Dried cured meat is even less popular, although there is a great demand for *biltong* south of the Zambesi. But even in southern Africa the emphasis is changing from meat production to tourist viewing and hunting, and the term "game reserve" would appear to be more appropriate than "game ranch" for these operations.

Ranching is a term that was first coined to describe a particular form of cattle farming in the western United States, and is associated with extensive grazing over large areas. Game ranching implies a form of husbandry similar to cattle ranching, and includes a measure of domestication. The objective of game ranching is to use the trypanotolerant, heat-tolerant and drought-resistant attributes of some game animals to increase animal production in areas that are of marginal value to conventional livestock. In this way they help to utilize the whole spectrum of vegetation with minimum damage to grazing lands.

Galana ranch

The Game Ranch Research Project, on which this article is based, was established on a 667 500-ha concession leased from the Kenya Government by Galana Game and Ranching Ltd., between Tsavo National Park (east) and the coastal belt. The ranch encompasses a vast plain of red and grey soils about 180 metres above sea level with a few small hills around the periphery. Rain storms originate from the coast and disperse as they move inland. The average annual rainfall decreases from 750 mm in the east to 250 mm in the west, while the annual potential evaporation is about 2 300 mm. The vegetation ranges from thick coastal bush, through fire-induced open plains, to *Acacia-Commiphora* bushed grassland in the west.

At present the ranch carries 14 000 head of Boran cattle, with a projected maximum of 26 000. The cattle are mainly confined to the central and eastern parts of the ranch where grazing is adequate, water can be provided and the challenge of tsetse

ALL PHOTOS COURTESY AFRICAN WILDLIFE LEADERSHIP FOUNDATION

and other biting flies is light. Wildlife have priority on the western side of the ranch, where a hunting lodge and the research project are situated. This area has an arid climate (Pratt *et al.*, 1966).

The criteria for game domestication include: ease of capture, taming and group herding, continued ability to exploit marginal areas despite the restraints imposed by domestication, ability to utilize the entire range, and palatable, marketable meat. The species chosen were fringe-eared oryx (*Oryx beisa callotis Ruppell*), African buffalo (*Syncerus caffer Sparrman*) — both common on the ranch — and eland (*Taurotragus oryx Pallas*), which were less common but had a reputation for ease of domestication (Posselt, 1963).

Game capture

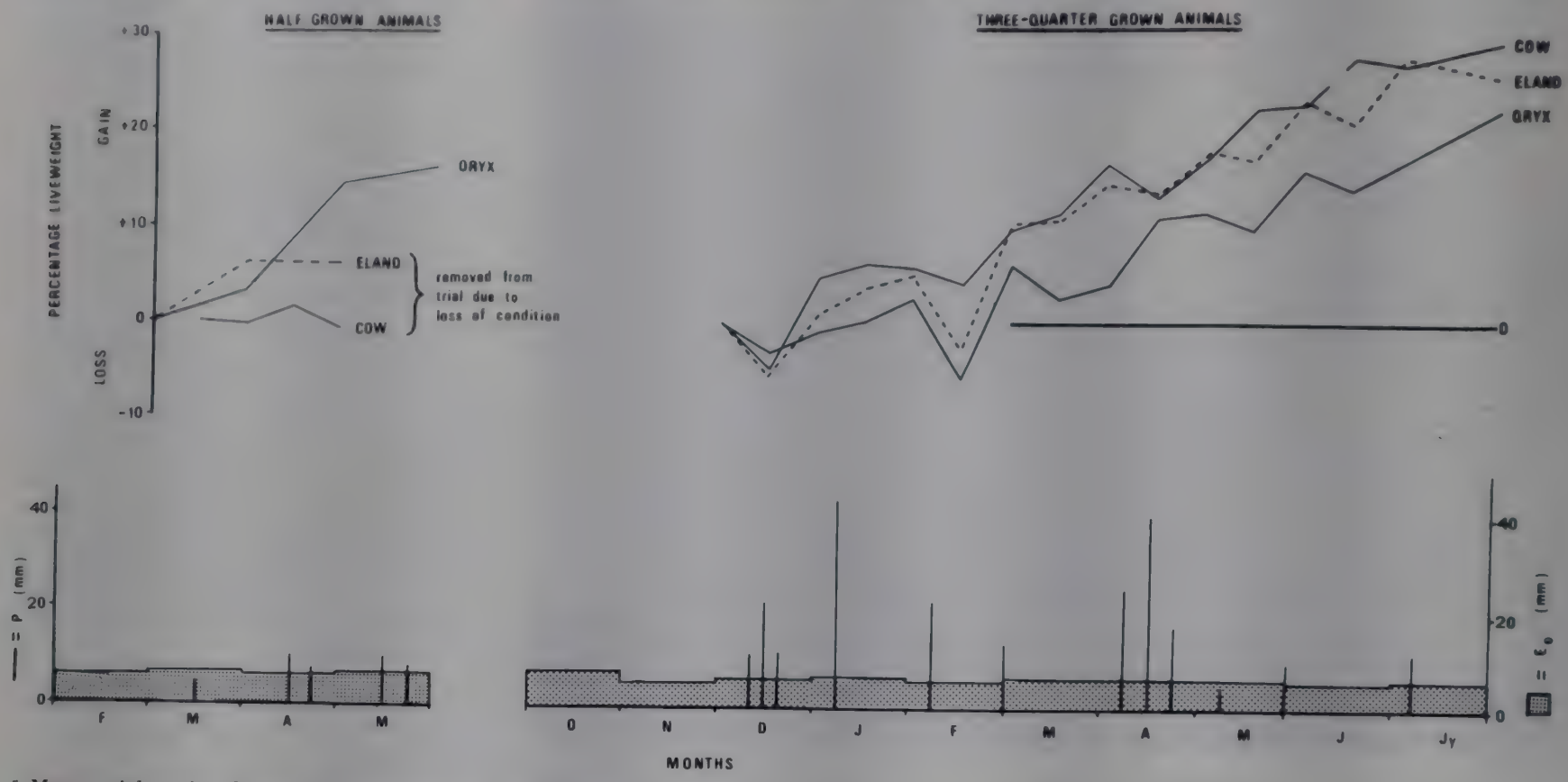
A wide variety of capture techniques have been used, from night catching with spotlights, darts or nets, to herd driving by helicopter into a plastic-walled corral, about 600 × 200 metres. The best way to capture oryx and eland is to locate them in open country and chase them in a medium wheelbase land cruiser. After a two to five minute chase, eland are roped with a noose on a pole, and oryx grabbed by the horns when they turn to challenge the vehicle. Buffalo are difficult to chase because they are seldom located in open country, but they are easy to approach in a helicopter from which they are dart-immobilized.

The captured animals have included all age groups, from suckling calves to those that calved within a few weeks of captivity, but half-grown animals are generally preferred.

Taming

Immediately after capture the animal is placed in a dark, well-ventilated crate, and transported to a dark, grass-padded cell. Water is provided *ad lib*, with a natural diet of grass, herbs and browse, supplemented with lucerne to offset the severe loss of

Growth of oryx, eland and boran cattle[1] in relation to daily rainfall (P) and potential evaporation (E_o)



[1] Mean weight gain of group (five to eight) of each species in separate paddocks at one stock unit per 11.25 hectares.

condition that may occur during the first few weeks of captivity. After the first week the grass padding is removed from portions of the pen walls, and thereafter, as the animals become accustomed to people, they are given more freedom. The size of the exercise areas is increased until the movements of the animals are controlled more by the herdsmen than by the proximity of fencing. The tamed animals are then absorbed into the main herds of each species. These herds are managed in the traditional African manner, being herded out to graze during the day and brought back to a corral or *boma* at night. There is no fencing to prevent escape,[1] and those game animals that stay with their herdsmen can be considered "domestic" in its simplest definition: "belonging to the household and being tamed, not wild."

[1] Editor's note: The possibility of using fenced areas is under consideration by some game ranchers. This would decrease contact between wildlife and domestic cattle and goats, facilitate day and night grazing and the employment of smaller numbers of herdsmen, and eliminate predator problems. However, game-proof fencing is very expensive.

Each species reacts differently to captivity. Buffaloes are aggressive after capture. Suckling calves tame rapidly, but older animals may remain suspicious for several weeks. Buffaloes proved easy to herd, and are not penned at night but allowed to sleep around the camp fire. Unfortunately, the bulls tend to become aggressive and dangerous as they grow older, and three bulls had to be killed after four years of age. As a result, the cows that came into oestrus afterwards sought out wild bulls for mating, but returned after service and calved in captivity. Cows with calves are quite placid, but castrated males can be boisterous.

Eland are nervous at first and liable to jump at the pen walls if startled, sometimes breaking horns or necks. Even calves born in captivity can be very wild during their first fortnight, but most captives calm down quickly and feed from the hand within a few days. Because they are selective browsers, eland tend to spread out and move fast when they are feeding, which has made them more difficult to herd than grazers. They are nomadic animals, and several have left the herd in search of better feed, or apparently to avoid worry from biting flies. The adult male is rather independent and liable to leave the herd for periods of up to three months, and then reappear at a cattle water trough and be reabsorbed into the domestic system as if he had

Table 1

Observed percentage composition of diet of animals in Galana Game Ranch research project

Animal	Vegetation	Percentage	Range of monthly values
Boran cattle	Grasses	88	100 - 77
	Herbs	5	0 - 15
	Browse	7	0 - 23
Buffalo	Grasses	91	100 - 65
	Herbs	2	0 - 6
	Browse	7	0 - 33
Oryx	Grasses	83	99 - 44
	Herbs	9	0 - 52
	Browse	8	0 - 28
Eland	Grasses	21	0 - 53
	Herbs	28	3 - 70
	Browse	51	18 - 94

never been away. Adult eland bulls have been known to gore and kill their keepers, but there have been no incidents on Galana, probably because of the mild temperament of the present stud bull.

Oryx tend to charge around their pens on the first day in captivity but settle down quickly and usually join the domestic herd within six weeks of capture. Wild oryx moving through the grazing area are a great attraction and there are always a few of the domestic herd at large. Unlike the eland, escaped oryx seldom move more than a few kilometres from the pens and frequently separate from the wild herds after a few days. They have been relatively easy to relocate but have to be chased like wild oryx to be recaptured. Only 10 percent of the oryx that have survived capture and taming are considered irrecoverable; these are newly released animals and adult cows that have gone off to calve in the wild. Only one of 23 surviving oryx calves born on the project has run away. Oryx bulls become independent at about three years of age but remain within about a kilometre of the night boma.

Restraint, dehorning and castration

Game animals at Galana have been trained to walk through a crush for their monthly weighing. Their reactions to physical or chemical restraints vary. Buffalo restrained in the crush are aggressive, but readily sedated. Eland put up only passive resistance but can jump out of a 1.5-metre crush if excited; they require potent anaesthetic mixtures. Oryx are seldom aggressive when physically restrained but struggle frantically for about half a minute and then lie down; they can be readily anaesthetized.

The horns of some young calves of all three species have been disbudded. This has not prevented some regrowth in eland and oryx or the development of the boss in buffalo. Less regrowth occurred when horns of about 20 cm in length on male eland and oryx were removed with an embryotomy wire. There has been no reason to attempt to dehorn female eland and oryx, or adult bull eland, which would be difficult. A dangerous bull oryx was dehorned with an embryotomy wire, resulting in immediate loss of his aggressiveness toward man but no loss of dominance in the herd, in which he was the largest animal. Male oryx have not shown aggressiveness before reaching marketable weight, when their horns may attain a length of 70 cm and a trophy value of K.shs.60 ($8.60).

Some males of each species have been castrated, but it is still too early to evaluate the effects.

Diet

The composition of the diet of domesticated buffalo, eland and oryx has been compared (Table 1) with that of Boran cattle (Field, 1975). Buffalo, cattle and oryx are predominantly grazers; herbs and browse usually make up only a small proportion of their diet. Oryx are more selective in their grazing and consume the nutrient-rich parts of both perennial and annual grasses. By contrast, eland only eat grass when it is green; browse makes up half and herbs one quarter of the eland diet.

Growth

The effect of these different feeding habits on growth was first demonstrated during trials with each species in separate paddocks at identical stocking rates, equivalent to 1 stock unit per 11.25 ha (see graph). The first trial started after two months without rain, and was abandoned after a further two months because the eland were in poor condition and the cattle had not gained weight. At that stage the oryx had put on a significant amount of weight and were in good condition. The second trial started under equally dry conditions, but 240 mm of rain over the next eight months produced good vegetation growth. At the end of the trial all three species had grown well and there was no significant difference between their growth rates. However, the graph shows that the growth rate of oryx, compared with eland and cattle, was lower after

PHOTO: HILL

Standing jump by 480-kg domestic eland bull over 1.5-m cattle fence in the Rift valley

African buffaloes with calves around camp fire. Note dehorned cow. PHOTO: TOMASYAN

heavy rainfall but higher under dry conditions.

These observations suggested that different grazing practices should be adopted for the different species. A transhumant herding system, using the steep rainfall gradient across the ranch, was adopted for cattle and their game counterparts — the buffalo; and for goats and their counterparts — the eland. The animals were herded at night into thorn bomas and portable predator-proof pens. The camp was moved to greener areas up to 50 km distant whenever the vegetation dried out. Initially the oryx were included in the search for better grazing, but when their weight remained almost static after several months in the higher rainfall belt in the east of the ranch they were returned to the west, and were walked only small distances from permanent yards to areas with greener grazing after local rainstorms. Dorper-type sheep have been added because they are thought to be the nearest grazing counterpart to the oryx. The comparative study of the feeding habits of eland and goats, and oryx and sheep, has not been completed.

Restraints on activity

Lewis (1975) investigated the effects of day grazing and night penning on game animals, which, in the wild, spend much of the night grazing and the day resting in the shade. It was found that the feeding activity of eland and buffalo (but not of oryx and cattle) was curtailed at higher levels of heat stress and solar radiation. Moreover, the selective feeders, eland and oryx, spent more time on feeding than the bulk grazers, buffalo and cattle. The species that suffered most from this form of management was the eland.

Water requirements

There was no permanent water on the 6 675 sq km of Galana apart from 24 km of river frontage on the southern boundary. Consequently, the provision of drinking water was a prerequisite for the establishment of the cattle ranch. It was noted that the water requirements of the different species of livestock would affect the cost of ranch development. Table 2 shows that oryx have 25 percent, sheep 45 percent, goats 50 percent and eland 60 percent of the drinking water requirements of cattle, when they are equated on the basis of metabolic weight.

The volume of drinking water represents the difference between the intake of water from the vegetation and the total requirements of the animal. Thus, grazers get more of their water requirement from the vegetation during the rains than browsers, and vice versa in the dry season. If vegetation moisture intake exceeds the total water requirement, the animal does not need to drink. Oryx have refused water for as long as 25 days, but the other species have drunk at least every second day. Any decrease in the frequency of drinking will decrease the trampling and grazing pressure by livestock around watering points.

It is worth noting that wild oryx and eland go without drinking water for long periods. In order to achieve this they must obtain most of their nutritional requirements between dusk and dawn, and their water requirements during the period of maximum relative humidity between midnight and dawn (King *et al.*, 1975). The restraints of domesti-

cation, imposing a daytime grazing regime, result in a relatively larger increase in the drinking water requirements of eland than of oryx.

Table 2

Average daily drinking water requirements of different species in the research project

	Boran cow	Eland	Small East African goat	Dorper sheep	Oryx
			Litres		
Per adult	40	20.7	3.0	3.6	4.8
Metabolic weight ($kg^{.75}$)	86	72.0	12.8	18.8	43.0
Water per cow equivalent (86 $kg^{.75}$)	40	24.8	20.2	18.0	9.6
			Percent		
As percentage of requirement of cow	100	60	50	45	25

Disease

The first game animals captured were examined for disease. They showed no clinical signs, negligible faecal worm egg counts, and nothing significant in blood smears and serum samples, with the exception of one buffalo that had antibodies against rinderpest.[2] At that time contagious bovine pleuropneumonia was enzootic in the cattle. They had also suffered a brief outbreak of East Coast fever and their infertility was thought to be due to *Brucella abortus*. Therefore the first cattle destined for the research project were quarantined before being mixed with the game animals.

Since then contagious bovine pleuropneumonia and East Coast fever have been eradicated, and brucellosis does not appear to be a problem. Healthy herds of domesticated game and livestock are maintained by routine prophylaxis which varies with the species.

Conventional livestock require constant protection against trypanosomiasis and tick-borne diseases, but the game animals do not.

In conventional livestock, mortality has often been secondary to the stress of transportation to Galana and first exposure to the harsh environment: 16 out of 40 Boran bulls died shortly after arrival with suspected anaplasmosis; 10 out of 30 recently introduced sheep died with signs of heartwater and haemonchosis.

The stress of capture and subsequent loss of condition have been the main cause of mortality in the game animals. Oryx are the only species that have been captured in sufficient numbers to warrant analysis. During the first three years 47 were captured; 28 percent died in the first six weeks and 13 percent subsequently. During the next three years, thanks to improved capture and handling techniques, mortality among another 46 oryx was reduced to 7 percent during the first six weeks and 4 percent subsequently.

Five out of 28 oryx calves born on the project died from poor mothering by first-calf cows or from pneumonia, possibly associated with lungworm.

Predation by lion, leopard, jackal and hyena has accounted for several sheep and goats, a few cattle, one or two oryx and an occasional eland during the year.

Reproduction

All species have bred on the research project (Table 3). The oryx sustained a calving interval of 10 months compared with 15 months for the cattle. Eland cows had difficulty in

Table 3

Breeding and slaughter data from domesticated game and conventional livestock

		Galana ranch					Rift valley[1]
		Oryx	Dorper sheep	Boran cattle	Small East African goats	Eland	Eland
Breeding							
First calf	*years*	2.5	1.3	3.2	1.2	3.7	3.0
Effective calving rate	*percent per year*	102	89	83	108	57	100
Slaughter							
Age	*years*	2.0	1.0	2.8	1.0	3.2	2.5
Liveweight	*kg*	135	40	350	35	300	300
Cold dressed weight	*percent*	57	45	52	46	55	55

[1] Preliminary data from R.E. Hill.

[2] Editor's note: Experience at Galana should not be interpreted to mean that all game animals are disease free. Elsewhere, internal and external parasites have been found in nearly all species, and their role in disseminating disease to domestic stock has yet to be assessed.

obtaining adequate feed to meet the added drain of lactation, and their calving interval has increased to 21 months.

Meat production

Live cattle, sheep, goats and oryx have been trucked 96 km to a coastal resort where they have been slaughtered in the same abattoir and subjected to meat inspection. The slaughter data presented in Table 3 include projections for eland. Buffalo have not been included because their meat is considered too tough for the luxury market. The oryx cold-dressed carcass weight of 57 percent, compared with 52 percent for cattle, is due to the extra lean meat on these animals (Ledger *et al.*, 1967). Consequently, oryx carcasses dry out faster than beef or mutton, and after hanging at about 27°C for eight hours and at +2°C for a further week they should be sold or deep frozen. Care must be taken in the preparation of the meat, which is best when it is marinated before being stewed in a rich sauce or pot-roasted liberally barded with fatty bacon.

Economics

Oryx meat has become popular at the coastal hotels, especially those catering for tourists from Europe. The meat is retailed as whole sides at K.shs.10-12/kg. The producer receives K.shs.6.50-10/kg plus the return of the skin and horns, valued at K.shs.100 and 60 respectively. Animals have been marketed at about 145 kg at 33 months, to ensure that the horns have reached trophy size (about 70 cm). The increased value to Galana of oryx, compared with sheep and cattle sold at the same coastal resort, is shown in Table 4.

Table 4

Value to Galana ranch of cattle, oryx and sheep sold at coastal tourist resort [1]

	Cattle	Oryx	Sheep
	Kenya shillings [2]		
Price per kg	6	8	6
Value of:			
carcass	1 100	656	108
hide	—	100	—
head	—	60	—
Total	1 100	816	108
Number per ranch unit	1	2	5
Value per ranch unit	1 100	1 632	540

[1] Cold-dressed carcass weights were 183, 82 and 18 kg respectively for cattle, oryx and sheep. — [2] US$1.00 = K.shs.7.

The sale of oryx meat to the African market has indicated that it will command nearly the same price as beef, but gross margins would be about 20 percent lower because of higher herding costs. This difference may well disappear in a tribal nomadic system, because oryx are more tolerant of trypanosomiasis and tick-borne diseases than cattle; but first they must be accepted as livestock. The herding of game animals has not presented any problems to Africans from six different tribes who have been employed on the Galana research project, although about half of them rejected the idea of taking oryx back to their villages.

Conclusions

The performance of game animals has been compared, often unfavourably, with the high standards set by the cattle, sheep and goats included in most studies. This emphasizes the need for game ranching to concentrate on areas of marginal value to conventional livestock.

Consequently, the buffalo with its bovine feeding habits has little to offer on Galana. But this species, or its smaller west African relative (*Syncerus caffer nanus*), might prove useful in the exploitation of coarse-grass areas infested with tsetse fly where meat is in short supply. The bulls would need to be polled and/or penned.

Eland are relatively unproductive in the hot semiarid environment of Galana under a day-grazing regime. This management system is much less of a handicap to the species in the Rift valley, as shown by preliminary data from R.E. Hill included in Table 3. The Rift valley eland herd is in an area where the ratio of rainfall to potential evaporation is twice as high as in Galana; feeding activity is less restricted by high heat loads because of the altitude of 2 000 metres; and much of the browse on offer during the dry months is under a shade canopy of leleshwa (*Tarchonanthus*). Nevertheless, the eland rancher should aim for a 24-hour grazing regime. This would mean putting up higher fences than cattle require. It cannot, however, be tried in the Rift valley, where large numbers of snares are set in the paddocks at night.

The species with the most potential in a semiarid environment is the oryx. It is able to gain weight on grazing that is below cattle maintenance, and has half the drinking water requirement of dorper sheep and one quarter that of Boran cattle when the species are equated on a metabolic weight basis.

REFERENCES

DASMANN, R.F. & MOSSMAN, A.S. 1961. Commercial use of game animals on a Rhodesian farm. *Wild Life, Nairobi*, 3: 7-14.

FIELD, C.R. 1975. Climate and food habits of ungulates on Galana ranch. *E. Afr. Wildl. J.* (In press)

KING, J.M., KINGABY, G.P., COLVIN, J.C. & HEATH, B.R. 1975. Seasonal variation in bodywater turnover by oryx and eland on the Galana Game Ranch Research Project. *E. Afr. Wildl. J.* (In press)

LEDGER, H.P., SACHS, R. & SMITH, N.S. 1967. Wildlife and food production with special reference to the semi-arid areas of the tropics and sub-tropics. *Wld Rev. Anim. Prod.*, 3(11): 13-37.

LEWIS, J.G. 1975. *A comparative study of the activity of some indigenous African ungulates and conventional stock under domestication.* London University. (Thesis)

POSSELT, J. 1963. The domestication of the eland. *Rhod. J. agric. Res.*, 1: 81-87.

PRATT, D.J., GREENWAY, P.J. & GWYNNE, M.D. 1966. A classification of East African rangeland, with an appendix on terminology. *J. appl. Ecol.*, 3: 369-382.

PHYSIOLOGICAL CONDITIONING IN RUMINANTS

and its practical implications

by E.R. Ørskov

It is prudent in a discussion of conditioned responses to draw attention to the originator of the concept (Pavlov, 1927), who defined it as follows:

"Conditioned reflexes are phenomena of common and widespread occurrence. Their establishment is an integral function in everyday life. We recognize them in ourselves and in other people or animals under such names as habits and training and all of these are really nothing more than the result of an establishment of new nervous connexions during the post-natal existence of the organism."

That these reflexes could influence nutrition was also established by Pavlov (1902), who is mainly credited with experiments on conditioned salivation in dogs but who also established an effect on other digestive glands.

Conditioned responses in ruminants with direct nutritional relevance

Conditioned responses and their relevance to practical nutrition are much less well documented than, for instance, adaptive responses to changes in nutrition or changes in temperature and endocrinological state. Experimental proof of a direct influence of higher centres on digestive secretion requires quite sophisticated techniques, but a conditioned response of a similar nature has no doubt been observed for as long as lactating ruminants have been hand milked or machine milked. This relates to the process of milk release, which is influenced to a large extent by extraneous stimuli. Stimulating receptors by massaging the udder is not necessarily required provided the surrounding routine, stockmen, noise of milking utensils, etc., signal unequivocally the milking time. On the other hand, stimulation of nerve receptors in the udder is not always sufficient to achieve milk release. A negative reaction to a new stockman or other interfering signals can inhibit it. The example of milk let down to illustrate conditioning is used here because the effect of the release of milk can be readily observed. Stimuli which in the same manner exhibit an effect on digestion are equally or even more important, but they can only be directly measured by sophisticated techniques.

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Conditioning of gastric secretion in ruminants

While the original observations on dogs were made many years ago by Pavlov, similar observations on ruminants are of more recent date. Much has been contributed to our knowledge on this subject by researchers at Melbourne. Carr, McLeay and Titchen reviewed this work in 1970. McLeay and Titchen (1970) showed that acid secretion in the

abomasum was increased when sheep were given the stimuli associated with feeding time but not fed. D.H. Carr and D.A. Titchen (unpublished report) observed changes in salivary secretion in sheep when teased with food and when the regular animal attendant walked past the animal room. A very interesting observation was made by D.A. Titchen and L.M. McLeay (personal communication): they encountered a profound reduction in gastric secretion in a sheep when one particular person was talking in the corridor not far from the animal room.

Conditioning of the motility of the digestive tract

In a similar manner to conditioning of secretion in the digestive tract there is now considerable evidence that gut motility is very sensitive to extraneous stimuli. Such evidence was discussed by Mielke (1961), and evidence of conditioning affecting intestinal motility (Ruckebusch, 1963a) and reticulo-rumen movement (Ruckebusch, 1963b) has been presented and referred to also by Carr *et al.* (1970).

Conditioning of the oesophageal groove reflex

The recent work on the nature of the reflex responsible for the closure of the oesophageal groove is of considerable interest, not only because it has now been well documented but because it is a reflex which can have a considerable and direct influence on the course of digestion, since it is the means by which young animals convey liquids direct to the abomasum, by-passing the rumen.

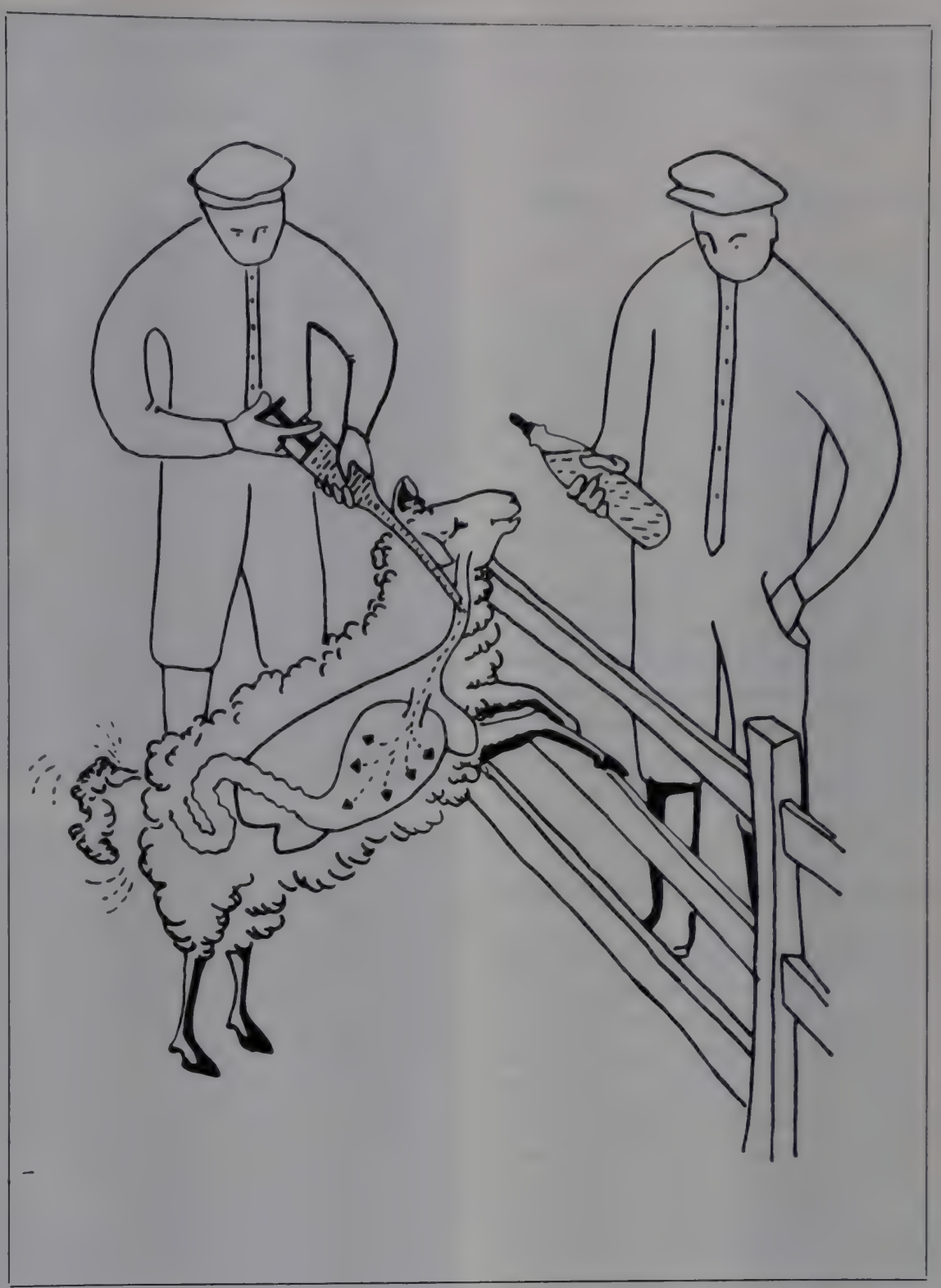
When Ørskov and Benzie (1969) reported their work on this subject, they were essentially in agreement with Watson (1944), who concluded that "the passage to the abomasum of liquids sucked by the lamb is not determined by the temperature or the composition of the liquid or by the posture of the animals while sucking nor by the act of sucking itself. It is the result of the actuation of the pattern of behaviour which surrounds the act of sucking." However, Watson was also led to infer that some mechanical stimulation by the teat was involved.

This finding was in contrast to those of many earlier workers, who had concluded that such factors as chemical composition and temperature of the liquid and posture while drinking were important. In later work, however, Ørskov, Benzie and Kay (1970) did not agree with Watson on the effect of mechanical stimulation, since liquid drunk from a trough would directly by-pass the rumen in the same manner as that taken from a teat. The proof that the oesophageal groove was conditionable was provided when it was shown that liquid infused into the oesophagus distal to the nerve receptors in the mouth and pharynx associated with groove closure (Comline and Titchen, 1951) entered the abomasum in animals when the external stimuli signalled feeding time. When no such signals were given liquids infused in this manner always entered the rumen.

Confirmative data were obtained by Newhook and Titchen (1974), who

When a liquid is infused into the upper oesophagus it will normally enter the rumen

showed that markers placed in the lips of the oesophageal groove were seen by radiography to move when lambs were teased, thus indicating groove closure. This was also observed in unpublished work by the author and R.N.B. Kay. The observation that the oesophageal groove was never closed when the motive for drinking was to quench thirst was confirmed by Ørskov and Benzie (1969), and this fact has important consequences in the management of systems in which it is desired to feed part of the diet in such a way that the rumen is by-passed (Ørskov, 1972a, 1972b).



When a liquid is infused into the upper oesophagus in a lamb stimulated by the sight of the bottle from which it normally drinks, it will enter the abomasum, thus showing conditioning of groove closure

Feeding systems in which the rumen is by-passed

The fact that water consumed to quench thirst enters the rumen is extremely important, because it means that only if the two motives for drinking (drinking for thirst and drinking in a state of juvenile excitement) are clearly separated is it possible to successfully utilize the oesophageal groove in the functioning ruminant. While this may sound a complicated rule to observe, it can be simply followed by ensuring that the animals have unrestricted access to drinking water and that the liquid suspension which is intended to by-pass the rumen is given in restricted quantities as a continuation of the milk-feeding regime. The latter rule, of course, implies that such systems must be based on artificial rearing and that feeding *ad lib* on milk substitutes is likely to extinguish the reflex in some animals (Lawlor *et al.*, 1971). The time of weaning from their dam is quite critical; the earlier the animals are weaned the easier it is to train them to drink from a teat or a trough. Delaying weaning to after two to three weeks of age will result in a large proportion of the animals failing to adapt successfully to the new feeding system.

It does not follow that the lambs or calves will, for instance, refuse to drink milk but they will not drink with any sign of excitement or pleasure. In such animals, most of the liquid consumed can be expected to have entered the rumen. Even when weaned at birth an animal occasionally fails to show the normal behaviour while drinking. Such animals are usually in poor condition and almost invariably the milk given will have entered the rumen.

Method of drinking

As mentioned earlier, the method of drinking (sucking from a teat or drinking from a bowl or trough) is not important for successful closure of the oesophageal groove. It is worth pointing out, however, that while trough feeding has obvious advantages as far as management is concerned, this regime has some disadvantages when one liquid is replaced by another, for instance milk replaced by a protein suspension. The new diet must be introduced very gradually to the trough-fed animals, since a strange smell can lead to refusal to drink (E.R. Ørskov and Thivend, unpublished results). In practice it may be advisable to include about 5 percent milk substitute in the suspension offered after wean-

ing. A change to a new diet with teat feeding is usually not recognized by the animals.

Concentration of liquid suspension

The dry matter concentration in the liquid suspension drunk is not critical. The main requirement seems to be that it must be sufficiently liquid to allow swallowing without further incorporation of saliva. An attempt was made by G. Wenham and the author to investigate this by gradually decreasing the water content in milk substitute until it was given in the dry form. When the lamb had to chew and incorporate saliva to facilitate swallowing, the oesophageal groove soon ceased to function. Feeding of solid food designed to enter the rumen can be pursued independently of liquid feeding.

Retention of reflex in mature animals

Provided the reflex is being constantly reinforced (i.e., the animals are given daily or every two days or so a drink following the routine and regime to which they are accustomed), it is possible to retain the reflex in almost all of the animals. Six lactating goats at the Rowett Research Institute which have now completed five gestation periods are still being used in experiments in which the rumen is by-passed, and there seems to be no loss in efficiency of groove closure.

Motility and secretion

The fact that secretion and gastric motility are greatly influenced by extraneous stimuli means that poorly defined factors like stockmanship cannot be ignored in the handling and general care of domesticated animals.

A decreased intestinal motility can have very serious consequences for intake and digestion, and can lead to a bacterial infiltration in the small intestine with well-known results (e.g., White *et al.*, 1969). The effect

Goats in their fifth lactation at their daily bottle feed

of an impaired gastric secretion on digestion and metabolism is poorly documented in animals. However, since many digestive enzymes are activated as a result of gastric secretion, an impairment will no doubt lead to inefficient digestion in the small intestine, so that a large number of substrates will reach the large intestine and give rise to scouring and dehydration. Another consequence of impaired gastric secretion is the effect of achlorhydria in the etiology of anaemia in man (e.g., Shearman *et al.*, 1966).

While factors influencing animal well-being may be inadequately understood, there is little doubt that the young, early-weaned ruminant, which is particularly sensitive, responds to kindness and attention like the human child, and unless good stockmanship can be provided early weaning and artificial rearing are unlikely to be successful. For all ruminant animals regular feeding times, feeding regimes, milking procedures and a regular stockman are very important factors.

As stated earlier, the effect of extraneous stimuli on gastric secretion and motility is difficult to measure. The fact that it exists raises questions with regard to the effect of new routines adopted in the intensification of animal production systems, e.g., effects of group feeding, conditions in calf houses, and so on.

TABLE 1. Comparison of nitrogen balance results of 11 lambs given protein supplements in liquid and dry form

	Nitrogen intake	Urinary nitrogen	Faecal nitrogen	Nitrogen retention
	Grams per day			
Barley + liquid protein supplement	22.9	6.5	6.6	9.8
Barley + dry protein supplement	22.8	8.7	6.2	7.9
SE of means	0.68	0.59	0.67	0.91

SOURCE: Ørskov and Fraser, 1969.

A comparison (Ørskov *et al.*, 1970) of casein, fish meal and soybean meal, given either in solid form so that they entered the rumen, or in liquid form so that the rumen was by-passed, showed the efficiency of N retention from casein to be improved by 31 percent, fish meal by 27 percent and soybean meal by 24 percent. A typical example of a N balance experiment is shown in Table 1, where the effects of giving a mixed protein supplement in liquid and dry forms are compared. The urinary N excretion was significantly decreased and retention increased when the supplement was fed in the liquid form.

The oesophageal groove can, of course, be used equally well for carbohydrate-rich foods which in turn might enhance the efficiency of energy utilization, since fermentation losses in heat and methane could be avoided if the carbohydrates with alpha-linked glucose polymers could be digested in the small intestine. Work on this aspect has shown that the small intestine of ruminants has a limited capacity for digestion of starch (Mayes and Ørskov, 1974) and even for glucose absorption (Ørskov *et al.*, 1971), and no capacity for sucrose digestion (Ørskov, 1973). By-passing the rumen with lipids has some interesting implications. Lipids entering the rumen in excess of 3-5 percent of the diet will interfere with fermentation of the cellulose and thus cause low feed intake. However, the capacity for absorption of lipids in the small intestine is very

The oesophageal groove

The object of the work on the oesophageal groove reflex at the Rowett Research Institute was to explore the possibility of using this mechanism as a means of by-passing the rumen with nutrients which were destroyed or partially destroyed as a result of rumen fermentation. In the young ruminant with a high level of feeding, the requirement for protein exceeds that which the microorganisms can make available by fermenting the carbohydrate. Protein supplements are, however, partly degraded in the rumen so the feeding of protein in a suspension, by-passing the rumen, could lead to a greatly increased efficiency.

TABLE 2. Effect of giving a high fat supplement (70 percent beef tallow) in dry form so that it entered the rumen, or in liquid form so that the rumen was by-passed, on voluntary intake of dried grass and total intake of digestible energy

Supplement	Level of supplementation (% of estimated metabolizable energy intake)	Intake of dried grass (g DM/kg $Wt^{0.75}$)	Total digestible energy (MJ/kg $Wt^{0.75}$)
None	0	55.1	0.68
Dry	7	48.8	0.68
Dry	14	45.1	0.72
Liquid	7	54.3	0.75
Liquid	14	51.2	0.81
SE of means		2.7	0.035

SOURCE: Bailey and Ørskov, 1974 (reproduced by courtesy of the Nutrition Society).

great; in fact, unpublished work has indicated that ruminants will absorb energy in the form of lipids sufficient to meet their maintenance energy need.

Table 2 shows the effects of giving lipids — so that they enter or by-pass the rumen — on the voluntary intake of dried grass by lambs and on the total intake of digestible energy. Lipids entering the rumen caused reductions in intake of dried grass so that no increase in total digestible energy was achieved. On the other hand, feeding of lipids so that the rumen was by-passed did not cause a significant reduction in intake of dried grass and consequently increased the total digestible energy intake. By-passing the rumen with lipids may thus provide a means of increasing energy intake or of altering the composition of the fatty acids in meat or milk.

Advantages

From the information available it would seem that the oesophageal groove could be used to advantage in the feeding of protein supplements to early weaned calves and lambs until they reach a stage of maturity at which their protein requirement is met by microbial protein. This occurs in Friesian calves at about 200 kg liveweight and in Suffolk cross lambs at about 35 kg liveweight (Ørskov, 1974). For carbohydrates, the use of the oesophageal groove has probably a restricted application owing to limitations on digestion and absorption from the small intestine. If lipids can be obtained at low prices, the oesophageal groove offers a means of taking them past the rumen with no deleterious effect on intake and digestion of roughage. Furthermore, the composition of fats given in this manner will directly influence the composition of the fatty acids laid down.

In comparison with the protection of proteins and lipids by chemical treatment (Ferguson *et al.*, 1967; Scott *et al.*, 1971), using the oesophageal groove has the advantage that there is no cost involved in chemical treatment and no uncertainty about over- or underprotection. It has the disadvantages that it must be based on artificial rearing, and requires restricted feeding of the liquid supplement. The choice must be based on the method that would be most suitable and economical in the production system under consideration.

REFERENCES

BAILEY, P.C. & ØRSKOV, E.R. 1974. The effect of ruminal or postruminal digestion of lactose or fat on the voluntary intake and digestibility of dried grass by lambs. *Proc. Nutr. Soc.*, 33: 45A.

CARR, D.H., MCLEAY, L.M. & TITCHEN, D.A. 1970. Factors affecting reflex response of the ruminant stomach. In *Physiology of digestion and metabolism in the ruminant*, ed. by A.T. Phillipson. Newcastle-upon-Tyne, Oriel Press.

COMLINE, R.S. & TITCHEN, D.A. 1951. Reflex contractions of the oesophageal groove in young ruminants. *J. Physiol., Lond.*, 115: 210.

FERGUSON, K.F., HEMSLEY, J.A. & REIS, P.J. 1967. Nutrition and wool growth. The effect of protecting dietary protein from microbial degradation in the rumen. *Aust. J. Sci.*, 30: 215-217.

LAWLOR, M.J., HOPKINS, S.P. & KEALY, J.K. 1971. The functioning of the oesophageal groove reflex and comparison of the performance of lambs fed individually and in groups. *Br. J. Nutr.*, 26: 439-448.

MAYES, R.W. & ØRSKOV, E.R. 1974. The utilization of gelled maize starch in the small intestine of sheep. *Br. J. Nutr.*, 32: 143-153.

MCLEAY, L.M. & TITCHEN, D.A. 1970. Abomasal secretory responses to teasing with food and feeding in the sheep. *J. Physiol., Lond.*, 206: 605-628.

MIELKE, H. 1961. Ueber die höhere Nerventätigkeit landwirtschaftlicher Nutztiere. *Wiss. Z. Karl-Marx Univ. Lpz.*, 4: 471-500.

NEWHOOK, J.C. & TITCHEN, D.A. 1974. Effects of vagotomy, atropine, heximethonium and adrenaline on the destination in the stomach of liquids sucked by milk fed lambs and calves. *J. Physiol., Lond.*, 237: 415-430.

ØRSKOV, E.R. 1972a. Reflex closure of the oesophageal groove and its potential application in ruminant nutrition. *S. Afr. J. Anim. Sci.*, 2: 169-176.

ØRSKOV, E.R. 1972b. Technology of feeding so the rumen is by-passed following artificial rearing. *II World Conference on Animal Feeding, Madrid, General report*, p. 627-639.

ØRSKOV, E.R. 1973. The capacity for digestion of carbohydrates in different segments of the gut in ruminants. In *Production disease in farm animals*, p. 18-31, ed. by J.M. Payne, K.G. Hibbitt and B.F. Sansom. London, Ballière Tindall.

ØRSKOV, E.R. 1974. *Factors influencing protein and non-protein nitrogen utilization in young ruminants.* 1st International Symposium on Protein Metabolism and Nutrition. EAAP Publication. (In press)

ØRSKOV, E.R. & BENZIE, D. 1969. Studies on the oesophageal groove reflex in sheep and on the potential use of the groove to prevent the fermentation of food in the rumen. *Br. J. Nutr.*, 23: 415-420.

ØRSKOV, E.R. & FRASER, C. 1969. The effect on nitrogen retention in lambs of feeding protein supplements direct to the abomasum. Comparison of liquid and of dry feeding and of various sources of protein. *J. agric. Sci., Camb.*, 73: 469-475.

ØRSKOV, E.R., BENZIE, D. & KAY, R.N.B. 1970. The effect of feeding procedure on closure of the oesophageal groove in sheep. *Br. J. Nutr.*, 24: 785-795.

ØRSKOV, E.R., FRASER, C. & CORSE, E.L. 1970. The effect on protein utilization of feeding different protein supplements via the rumen or via the abomasum in young growing sheep. *Br. J. Nutr.*, 24: 803-809.

ØRSKOV, E.R., MAYES, R.W. & PENN, A. 1971. The capacity for removal of glucose from the small intestine in mature sheep. *Proc. Nutr. Soc.*, 30: 43A-44A.

PAVLOV, I.P. 1902. *The work of the digestive glands.* London, Griffin.

PAVLOV, I.P. 1927. *Conditioned reflexes (OV Anrep translator).* London, Oxford University Press.

RUCKEBUSCH, Y. 1963a. Liaisons reflexes conditionnelles chez les ruminants. I. Motricité gastrique. *Bull. Acad. vét. Fr.*, 36: 91-97.

RUCKEBUSCH, Y. 1963b. Liaisons reflexes conditionnelles chez les ruminants. II. Rumination. *Bull. Acad. vét. Fr.*, 36: 98-107.

SCOTT, T.W., COOK, L.J. & MILLS, S.C. 1971. Protection of dietary polyunsaturated fatty acids against microbial hydrogenation in ruminants. *J. Am. Oil. Chem. Soc.*, 48: 358-367.

SHEARMAN, D.J.C., DELAMORE, L.W. & GARDNER, D.L. 1966. Gastric function and structure in iron deficiency. *Lancet*, I: 845-848.

WATSON, R.H. 1944. *Studies on deglutition in sheep.* Melbourne, Council for Scientific and Industrial Research. Bulletin No. 180. 80 p.

WHITE, F., WENHAM, G., SHARMAN, G.A.M., JONES, A.S., RATTRAY, E.A.S. & MCDONALD, I. 1969. Stomach function in relation to a scour syndrome in the piglet. *Br. J. Nutr.*, 23: 847-858.

The Kenya National Artificial Insemination Service

An article on artificial insemination in developing countries was published in World Animal Review 9. As a follow-up to that article, we present here a case study of the organization and implementation of a successful AI scheme in a developing country.

by G.R. Duncanson

The Kenya National Artificial Insemination Service operates in seven of the eight administrative provinces of Kenya, the exception being the arid northeastern province. However, effort is concentrated in the more productive areas with an annual rainfall of 400 mm and over, which are situated in the highlands, around Lake Victoria and on the coastal strip.

The total population of grade female cattle in the country, with more than 50 percent *Bos taurus* blood, is approximately 500 000. Of these, some 277 000 are covered by the national artificial insemination service. A further 45 000 zebu (*Bos indicus*) females are normally presented for service annually, but these represent only a small proportion of the total zebu cattle population of 10 million.

The Kenya National Artificial Insemination Service is controlled by the National Artificial Insemination Board, whose chairman is the Director of Veterinary Services. This board directs its activities through an Assistant Director of Veterinary Services. The recurrent funds for the operations of the service are provided by the Kenya Treasury through the Ministry of Agriculture. Since July 1966, development funds have been provided by the Government of Sweden.

Semen is provided from a Central Artificial Insemination Station whose policy is directed by a management committee chaired by the Director of Veterinary Services. The secretary to the committee is the executive officer, who is also the veterinary officer in charge of the day-to-day running of the Central Artificial Insemination Station.

History of artificial insemination in Kenya

Artificial insemination in cattle was first performed in Kenya in 1935 by Dr. J. Anderson. It was confined to the collection of semen from bulls on individual farms for use on cows in the farms from which it was collected. It was used to combat epivag and other infectious infertility diseases. A survey carried out by Dr. Anderson at that time revealed that over 35 percent of bulls tested were sterile. This emphasized the importance of AI and so its use grew steadily. The first AI scheme was set up in Kenya in 1941 on the basis of a community bull scheme. This was followed in 1942 by a scheme operated by the Limuru Cattle Breeders' Association, which continues to this day and is linked to the Kenya National Artificial Insemination Service.

The Central Artificial Insemination Station was started in 1946 for distribution of semen throughout the country. Initially there were some bulls at substations, but these were subsequently disbanded.

AI schemes were set up in many areas for both large and small farms. By 1958 there were 12 schemes. However, the use of AI fell to a very low level in 1963 with the splitting up of large farms and the increased costs involved. Sales of semen from the Central Artificial Insemination Station dropped to such a point that it was hardly economical to continue. However, in 1964, with the demand created by the newly established settlement farms, semen sales began to rise again. The demand for dairy stock increased so rapidly that it was decided that the AI service should be subsidized. Plans were put forward to the Swedish Government which resulted in the initiation of the Kenya National Artificial Insemination Service in July 1966.

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Bulls at the Central Artificial Insemination Station in Lower Kabete, Kenya

Central Artificial Insemination Station

This station is located in Lower Kabete and has over 125 bulls, of which 110 are from the four dairy breeds, Ayrshire, Friesian, Guernsey and Jersey. The rest belong to the Sahiwal, Simmental, Boran, Charolais and Hereford breeds. In the early years bulls were purchased from abroad as adults, then in later years as calves, but more recently a contract mating programme has been initiated. Semen from some of the best bulls in the world is imported and used on the best producing cows in Kenya, which are identified by comparing their performance with that of contemporaries maintained under similar conditions. The Central Artificial Insemination Station then has the option of buying any male progeny from these matings. Associated with this is a progeny testing programme which was started in 1969, using data from the Kenya Milk Recording Scheme. This facilitated accurate assessment of the genetic potential under Kenyan conditions of the dairy bulls maintained at the Central Artificial Insemination Station.

Over 700 000 doses of semen are produced annually at the station, mainly for use in the national AI service schemes. Of the station's output of semen 1 percent is exported and another 3 percent is sold to private and government farms not covered by the service. In 1973, about 20 percent of the semen was deep frozen in liquid nitrogen and 80 percent used at room temperature (16-25°C). The latter was obtained from the four dairy breeds and collected and delivered to the schemes twice a week.

The bulls are kept in individual paddocks with small separate covered pens in blocks of two. One attendant looks after four bulls. Semen is collected centrally, and checked by a veterinarian in the laboratory immediately after collection and before dilution and further processing.

A coconut milk extender is used for room-temperature semen. For deep-frozen semen an extender containing glycerol is used and the semen is then packed in 0.5-ml plastic straws in liquid nitrogen. Deep-frozen semen is produced from all the breeds standing at the Central Artificial Insemination Station, and will be increasingly used by the national service and would also be available for export.

National Artificial Insemination Service

The insemination service consists of two sections, both based at Kabete. These are the field services section and the planning and development section. Both are now staffed by Kenyan nationals.

The Kabete headquarters of the field

Right: Semen testing at the Central Artificial Insemination Station laboratory.

Below: AI recording at a roadside crush in a small farm area. Crushes are located at intervals of approximately 1.5 km. Over 75 percent of all inseminations are carried out at roadside crushes.

services section is composed of two officers, a personal assistant to the Assistant Director of Veterinary Services in charge of AI, an executive officer responsible for AI stores, and supporting office staff. The field staff consists of 20 livestock officers, each of whom is in charge of an AI scheme. Ten of the larger schemes are provided with clerical staff. There are also drivers of motor vehicles in certain schemes where semen has to be transported to nonmotorized static points; but generally the 260 inseminators employed in the field drive their own vehicles. Each inseminator averages five inseminations per day.

Of the 490 000 inseminations performed annually, 93 percent are carried out by motorized inseminators. The rest are performed by inseminators working from nonmotorized static points, usually on bicycles. This is wasteful of manpower, because the existing 56 nonmotorized static points average only 1.5 inseminations a day. This system provides a poor service to farmers: it is unreliable owing to communication difficulties, and supervision is impossible except on the twice-a-week semen delivery days. Room-temperature semen is used because the liquid nitrogen cylinder is too bulky to carry on a bicycle (this problem has been overcome on the remote island of Lamu by using a community donkey).

About 8 percent of the inseminations are performed by inseminators on motor cycles. These cycles have been found to be unreliable on account of frequent breakdowns and difficulties in handling on rough roads. Also, they cannot carry liquid nitrogen cylinders. Four-wheel-drive vehicles are expensive to run and are only required in a few areas where the roads are particularly bad. (However, they are useful for transporting broken-down motor cycles!) They are used for about 2 percent of the inseminations.

In order to save costs, increase efficiency and assist in supervision, the majority of the inseminations are carried out on motorized daily runs as opposed to motorized static points. On a daily run the inseminator leaves the scheme headquarters at the same time every morning and goes out on a set route with timed departures from insemination points. In the small farm areas these points are roadside crushes. They are spaced at intervals of approximately 1.5 km along the route. The farmers then know at what time they should bring their cows to the crush for insemination. The average daily run for each inseminator using a car is 120 km and includes up to 60 crushes, resulting in about 15 inseminations per day. The inseminators riding motor cycles have daily runs of about 50 km with up to 25 crushes, averaging 3.5 inseminations each per day. The inseminators operate daily runs in the large farm areas also, but the inseminations are performed on the farm at a crush near the road. In

order to save mileage the farmer displays a flag at his gate if AI is required.

In some areas where farms are small visits continue to be operated on a motorized static point system. Farmers write down their names and addresses in a book that is kept at the office of the local chief or in a shop. The inseminator calls at this point and visits the farms indicated. But as this system results in only a small number of inseminations per day it has been largely discontinued. In 1973 there were only 21 runs working on static points as opposed to 91 on roadside crushes.

Transport is an expensive component of the service. In 1973, 140 saloon cars, 96 motor cycles and 11 four-wheel-drive vehicles travelled over 5 million km. As 85 percent of this distance was related directly to insemination work, it means that every insemination required about 10 km of travel.

The organization of a typical scheme, performing 80 to 100 inseminations a day, is as follows:

Offices — Semen room, clerical office, office for the officer in charge, changing/washing room with lavatory, and garage.

Staff — One livestock officer, 15 inseminators and one clerk (this provides 1.5 inseminators per run or static point which enables the service to function every day of the year).

Vehicles — One four-wheel-drive vehicle, eight saloon cars and three motor cycles (this offers 1.3 cars and 1.5 motor cycles per run, and makes allowance for repairs and delays in replacement).

Operations — Five runs and one static point covered daily by cars, two runs and two static points covered daily by motor cycles.

The basic AI recording is done in the field by the inseminators. Every farmer has an AI number and a file with a card for each cow. For the first insemination an AI certificate is completed by the inseminator and four carbon copies made. The first copy is returned by the inseminator to the AI scheme office. Should the animal return to service, the details are added to the original and the remaining copies. The second copy is then submitted to the office. A similar procedure is followed for the third insemination. Should the animal return to service more than three times, an infertility treatment of the uterus with penicillin and streptomycin is recommended and recorded. This is followed by a fourth insemination. If this is unsuccessful, either the cow is culled or a new certificate purchased.

A farm record sheet is completed at the AI scheme office before copies of the certificates are sent to the AI recording centre at headquarters, where the 60-90 day non-return rates for each inseminator, each bull, each scheme and the whole service are calculated on a monthly basis.

All cows are identified by a simple ear notch which is made by the inseminator at the time of first service.

The planning and development section is staffed with two veterinary officers and two livestock officers (AI) who carry out AI field surveys and infertility investigations and also plan and assist in the reorganization and extension of the field service. Recording clerks attached to this section carry out the data processing of the AI certificate copies from the field.

Planning and development

During the last eight years not only have the staff planned the expansion of the service, but they have also helped the officers in the field by extended visits of up to four months to put the development plans into action. This work has been of great importance, but the need for it is expected to gradually diminish.

However, the work of the progress

Basic practical training in artificial insemination is offered at Kabete

monitoring unit, or field survey team, consisting of two veterinarians and one livestock officer, will not diminish in importance. The team examines regularly all the stock, together with their AI certificates, on randomly selected farms in four districts. In this way the real results of the service can be assessed. Data obtained over the last eight years are of particular interest:

1. The stocking rate has not risen in Kiambu district; the 15 percent surplus of AI-sired heifers has been sold to other districts.
2. Approximately two thirds of heifers born by AI come into production.
3. Six inseminations are required to produce a heifer which will come into production.
4. Calf mortality has risen to 17 percent in the period; the causes are as yet unknown.
5. The calving interval dropped from 467 days in 1966 to 400 days in 1972.
6. The age of heifers at first insemination has dropped from 630 to 544 days.
7. The pregnancy rate to all inseminations is 48 percent. Lowest rates are recorded during the months from January to April, which coincide with the period of low rainfall.
8. The number of inseminations per pregnancy (based on animals that have eventually become pregnant) has now come down to well below two.
9. Over 85 percent of all animals served by AI have become pregnant.

Precise information such as this, and not estimates, is vital for the development of an AI service.

An AI training team, consisting of two livestock officers and two demonstrators, is associated with the planning and development section. This team has changed its emphasis from the basic training of new recruits to refresher courses and follow-up activities in the field. During 1973 three six-week courses of basic training in AI were attended by 47 students, while 153 inseminators in the national artificial insemination service were given refresher courses lasting from one to two weeks. Every inseminator in the service attends such a course every other year. If an inseminator's non-return rate is low, he is given an extra course. In addition, seven livestock officers with diplomas in animal husbandry were given a five-week course in AI and AI supervision.

Another important part of the training is concerned with driving motor vehicles. In 1973, 45 candidates passed the driving test for cars and 72 the test for motor cycles, following training at the AI driving camp.

The aims

The main aims of the Kenya National Artificial Insemination Service are as follows:

1. To control infectious breeding diseases.
2. To improve the productivity of the national herd.
3. To upgrade the low-producing zebu stock.

These aims are designed not only to increase milk and meat production, but to make this production more economical. This means that the activities of the service should result in an increase in the income and the standard of living of farmers, particularly small farmers in the farming areas with high potential. It should improve nutritional standards in the farming community and among consumers in its areas of operation, as well as in urban areas through increased milk supply. The service should also help to reduce foreign exchange expenditure on imports of cattle and cattle products, and increase foreign exchange income through the export of dairy products, beef, semen and live cattle.

The problems

The two major problems affecting the service are a low standard of animal husbandry and a lack of strict disease control, particularly tick control. These two factors are outside the scope of this article, but work on them must proceed together with AI. It is difficult to envisage their preceding the AI service, because without grade cattle there appears to be little need for the farmer to improve either husbandry or tick control. It is equally true that without either of the latter the grade cattle will die. It is only by using AI that a gradual upgrading process is achieved, giving the farmers time to adapt to the changes introduced. Schemes involving the mass introduction of adult grade cows into an area do not allow time for such adaptation, and often tend to be failures.

Where does the service go from here?

The main problems in the setting up of the Kenya National Artificial Insemination Service have been resolved with time. The following changes have yet to be made:

1. Complete motorization, using saloon cars for daily runs, in order to increase efficiency and supervision.
2. Complete change-over to deep-frozen semen, in order to lower wastage and frequency of delivery; this would also facilitate the use of proven sires and a more accurate selection between sires on test.
3. Improvement in the accuracy of AI recording to aid monitoring and the future planning of the service.
4. Expansion of the milk-recording scheme so that contract mating and progeny testing programmes can be enlarged.

The goal of the service to produce high-quality dairy heifer calves for Kenyan farmers has been achieved to the extent that 100 000 crossbred and grade heifer calves are now produced annually. They cost K.shs.50 ($7.15) each to produce, which is inexpensive by any standard. But at present only about 4.5 percent of this cost comes from the farmer in direct fees. Some means will have to be found to raise sufficient funds to run the service through a levy on dairy products.

PROSPECTS FOR INCREASING WORLD POULTRY PRODUCTION

by H.F. El Issawi

The inadequacy of high-quality protein in the human diet is one of the principal reasons for the poor levels of nutrition in the third world. Efforts to increase the output of animal protein to provide the theoretical safe level required of 29 g per head per day (FAO, 1973a) appear as yet to have been unsuccessful. An average world production figure of 8 kg per head of human population means that only 22 g of animal protein was available per head per day in 1970, which is below the minimum requirement for human nutrition. This deficiency is particularly severe in the Far East and African regions.

World protein production

On a world basis, total protein produced from poultry in 1973 was 4 323 405 tons, which was 17 percent of the total protein produced from all farm animals (25 348 000 tons). Table 1 shows the increases obtained in world animal protein production from 1961-65 to 1973. These were 18.8, 8.2, 32.1 and 50.5 percent, respectively, for cattle and buffaloes, sheep and goats, pigs, and poultry.

There was considerable variation in the production figures of the three categories of countries: in the developed, developing and centrally planned countries the increases were 15.3, 32.0 and 35.2 percent respectively. The contribution of poultry and poultry products to these increases was 42.6, 77.3 and 54.2 percent.

In the Latin American, Near East and Far East regions there were increases of more than 70 percent in protein production from poultry, and it was only in Africa that a relatively low figure (40 percent) was registered. The high potential of poultry for increasing protein output for human consumption may be attributed principally to high feed conversion rates. Clayton (1975) reported that 45 lb of barley or its equivalent were required to produce 1 lb of lean meat from sheep, 35 lb for beef, 12 lb for pigs and 10 lb for chicken and turkey (2.2 lb = 1 kg).

The emphasis given to any sector of the animal industry in national plans, therefore, would be influenced by the efficiency of the species in converting feed into high grade animal protein. This is because protein is the most critical ingredient in short supply and animals compete directly with humans for these requirements. This competition extends also to ruminants: directly, for the concentrates which form part of their diet; indirectly, because of the pressure to produce crops for human food rather than pasture on arable land.

Much of the commercial supplies of animal protein today come from large industrialized systems of poultry production. These have evolved gradually from backyard or subsistence poultry keeping, through rather intensive production at the small farmer level, to large producing and marketing units that have been facilitated by improved transport and communication services and vastly improved technology. The modern poultry industry is thus divided into specialized sectors, dealing with breeding and hatching, feed production, disease control, equipment production, processing, egg packing, and marketing. Since feed represents over 65 percent of total production costs in indus-

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Industrialized poultry production is based on specialized strains of poultry that have been successfully developed by international breeders

trialized systems, its availability is the first consideration in any forecast of world prospects for increased poultry output.

Feed resources

The development of industrialized poultry production depends basically on the existence of an adequate infrastructure within a country: the necessary institutional structure within the government, well-developed transportation and communication systems, efficient feed storage and handling systems, and a strong market economy.

However, there may be constraints to development even where an adequate infrastructure exists:

— inadequate banking facilities and credit for the necessary capital investment;

— low output of domestic feed ingredients (although some countries have been able to develop industrialized systems of poultry production based on imported feed);

— limited veterinary services and low vaccine production capacity;

— inadequate agricultural education and research base, and lack of personnel trained in poultry production;

— poor marketing systems and marketing channels.

The inadequacy of domestic feed ingredients looms large in most discussions concerning the possible development of industrialized poultry production in developing countries, because of the competition between man and livestock for grains. It is therefore relevant to note that even in India, which is notoriously short of grains for human consumption, the poultry industry has grown remarkably in the past 10 years with feed based mainly on imported grains. With only 25 percent of the standard poultry ration made up of grain and 75 percent of by-products, it is possible to convert the grain into the same weight of animal protein. Many countries with a high per caput income and a strong market demand for livestock and poultry products have found it economically feasible to import grain for feeding.

World production of feed grains was estimated in 1972 at 633.3 million metric tons (FAO, Committee on Commodity Problems, 1973). Less than one fifth is produced by developing countries. In 1972, western Europe and Japan imported 34.1 million tons out of an estimated world trade in feed grains of 55.4 million tons.

Insofar as feed ingredients of animal protein origin are concerned, world requirements are estimated at 7.3 million tons per year. It is true that the availability of fish meal (estimated annual production 3.9 million tons), meat meal and dairy by-products is limited. But the development of unconventional sources of feed protein of high biological value, in the form of yeasts and fungi, is promising. It has been estimated by Abbott (1973) that world production of such protein is about 800 000 tons, and Walker (1974) has stated: "It is theoretically possible for known world resources to yield about 20 million tons of paraffin yeasts a year over a period of about 30 years."

World production of vegetable oil cakes and meals is estimated at 11.2 million tons of protein equivalent (FAO, Committee on Commodity Problems, 1974). Trade in these commodities is worldwide, but the major importing areas are western Europe and Japan, where demand for oil cakes has increased in recent years and is growing much faster

than for fats and oils, reflecting a rising demand for livestock products and more intensive feeding practices. In 1972, the total export trade in soybeans was estimated at 15.6 million tons, of which the United States alone exported about 80 percent (FAO, Committee on Commodity Problems, 1974).

Economic and technical problems (lack of investment resources and production incentives, poor cultivation practices, inadequate disease and pest control, low use of fertilizers, inadequate transport and marketing facilities) hamper the expansion of oilseed cake and meal production (particularly soybean) in developing countries. It may therefore be concluded that many will find it difficult to procure sufficient feed supplies to establish large-scale poultry production systems. To overcome this situation, adequate capital has to be secured, either locally from exports of their own raw materials or manufactured goods, or through international funding based on long-term low-interest loans. Such financial resources should be used to increase domestic grain and soybean production, with serious efforts to overcome the other related problems.

Discussions on limited feed resources should not detract attention from the possibilities for increased rural poultry production, which represents 80-90 percent of total domestic output in many developing countries. National schemes are therefore required to promote poultry production at existing levels.

Improvement of breeding stock

Breeding to upgrade local stock involves either the importing of improved strains or practising selective breeding among local strains. A successful example of upgrading schemes, combined with disease control measures and improved management, is provided by the early development of the poultry industry in India (McArdle, 1969).

Selective breeding can only be undertaken if the native stock possess a moderate to high genetic potential for improved performance under adequate management. Some examples of successful selective breeding, reported at the Fourth FAO Expert Consultation on Animal Genetic Resources (FAO, 1973c) related to "Partridge Greenlegs" in Poland, various local breeds in Argentina, the "Desi" in India, the "Wagogo" in Tanzania and the "Dokki 4" in Egypt.

TABLE 1. Protein production from different species of livestock [1]

	Percent increase of 1973 over 1961-65				Total protein		
	Cattle and buffaloes (meat/milk)	Sheep and goats (meat/milk)	Pigs (meat)	Poultry (meat/eggs)	1961	1973	Percent increase
	Percent				*Thousand tons*		*Percent*
Developed regions	8.3	5.9	30.0	**42.6**	10 762	12 415	**15.3**
North America	[2]—	[2]—	8.9	24.5	4 277	4 503	5.3
Western Europe	11.5	4.3	38.4	50.1	5 461	6 436	17.8
Oceania	16.9	20.3	72.7	55.5	623	747	19.9
Others	3.0	18.2	181.5	129.8	401	729	81.8
Developing regions	27.1	19.9	43.6	**77.3**	3 575	4 719	**32.0**
Africa	16.3	12.0	55.5	**40.3**	406	487	19.9
Latin America	31.7	2.3	46.0	**88.3**	1 411	1 952	38.3
Near East	28.9	23.1	[2]—	**73.0**	541	700	29.4
Far East	24.2	25.2	38.7	**82.0**	1 214	1 576	29.8
Others	50.0	[2]—	[2]—	[2]—	3	4	33.3
Centrally planned regions	34.9	[2]—	32.1	**54.2**	6 074	8 214	**35.2**
Asia	13.0	5.2	24.6	38.4	1 417	1 785	26.0
Eastern Europe, U.S.S.R.	36.6	[2]—	40.7	37.7	4 657	6 429	38.0
World	**18.8**	**8.2**	**32.1**	**50.5**	20 411	25 348	**24.2**

SOURCE: FAO, 1974.

[1] Meat yield percentage from cattle, buffaloes, sheep and goats is calculated at 50 percent, and from pigs and poultry at 65 percent; protein percentage in meat from cattle and buffaloes 15 percent, in meat from sheep and goats 12 percent, in meat from pigs 11 percent, in meat from poultry 14 percent, in milk from cattle and buffaloes 3.5 percent, in milk from sheep and goats 5 percent, in eggs from poultry 11 percent. — [2] No increase.

Industrialized poultry production, however, must be based on specialized strains that have been successfully developed by international breeders. Over the past 30 years these breeders have invested large amounts of capital for the development of these strains, which have proved to be profitable under intensive large-scale production systems. Using the techniques employed by maize breeders, the foundation stock breeders and franchise hatcherymen developed inbred strains and inbred lines which, when crossed, produced broilers and layers with a remarkable degree of hybrid vigour and uniformity.

Breeding programmes call for the maintenance of large populations, and the continuous application of high selection intensities to achieve improvements in efficiency. Accurate recording systems and trained statisticians and geneticists are required to operate such programmes. It should be noted that each grand-dam housed

Priority is given to feed availability in industrialized poultry production systems

is capable of producing 5 000 commercial chicks in two generations. This means that to justify initiating a breeding programme based on a minimum of 5 000 grandparent layers, the market demand for day-old broiler chicks should be at least 20 million a year. This does not mean that countries which have a limited market for broiler chicks or which lack technical facilities cannot industrialize poultry production. The cost of broiler chicks in such operations amounts to only 4-5 percent of the total invested cost in a broiler enterprise (U.S. Department of Agriculture, 1968), so that if a group of countries could operate on a regional basis, with one of the international breeders or franchise hatcherymen, the proposition could become commercially viable.

The manufacture of moulded paper egg trays in India, which started in 1967, lowered egg breakage during transport from 17 to 2.5 percent

Disease control

Modern systems of poultry production owe their existence largely to rapid progress in health and disease control. It is now possible, for instance, to eradicate or keep under control pullorum disease in most organized breeding farms and hatcheries. There has also been considerable progress in the eradication of infection with pathogenic *Mycoplasma* and it is possible that Marek's disease might similarly be eradicated in the future. For other diseases, such as Newcastle disease, infectious bronchitis, avian encephalomyelitis, laryngotracheitis and fowl pox, measures have been developed to keep them under control and thus reduce the financial losses they inflicted on the industry in the past.

In developing countries, the establishment of diagnostic centres for diseases and a ready supply of vaccines are vital for the promotion of poultry production. Sufficient veterinarians trained in poultry diseases must be available. Governments should issue regulations for the sanitary operation of breeding farms and hatcheries, and for the proper utilization of poultry vaccines.

The establishment of the poultry industry in Pakistan was hampered by disease. Estimates of mortality in commercial flocks near Karachi in 1971 are shown in Table 2. The high losses were mainly due to a lack of basic facilities such as diagnostic services and personnel, and a shortage of essential medicines, vitamin supplements, feed additives and standardized and potent poultry vaccines, added to faulty nutrition and improper management. However, with the expansion of services to poultry farmers under the Poultry Research Institute project, and with the provision of training courses, considerable progress has been made in disease control. As a result, the production

TABLE 2. Mortality in poultry at different ages in flocks of different size, in Karachi, 1971

Layer farms						
Flock size	Up to 200	201-1 000	1 000-2 000	2 000-3 000	3 000-10 000	Over 10 000
Average monthly mortality:						
brooding phase . . .	4.8	6.8	3.2	2.8	4.2	2.0
adult phase	3.6	2.8	3.7	1.6	3.1	2.4
Broiler farms						
Flock size	Up to 2 000		2 000-6 000		Over 6 000	
Average monthly mortality	6.5		5.6		6.1	

SOURCE: UNDP/FAO Poultry Research Institute project.

of poultry meat in Pakistan has increased: in 1971 it was 19 000 tons, rising to 21 000 and 24 000 tons in 1972 and 1973 respectively (FAO, 1973b).

To accomplish the objectives of a national programme, it is necessary that governments should create new training institutions, where necessary, or improve existing ones (both government and private). The advisory service should also be strengthened. Many developing countries attempt to fill this gap by training more veterinarians and by strengthening extension services to upgrade management levels. But demonstration and training centres specifically devoted to poultry production are either nonexistent or inadequately supported and equipped.

In developing countries with a fast-growing poultry industry priority should be given to training and research in: performance testing of commercial strains, feed and nutrient requirements, management systems and disease control.

Marketing

Improved marketing methods (egg-packing and broiler-processing plants) are prerequisites for industrialized poultry production. The formation of cooperatives to manufacture balanced feed mashes and to market poultry products could be encouraged, for the benefit both of producers and consumers. India provides an interesting example of a marketing infrastructure for broilers and eggs set up with government assistance. Panda (1974) reported that the Maharashtra Agricultural Development and Fertilizer Promotion Corporation succeeded in raising the monthly broiler consumption in Bombay from 5 000 to 200 000 birds in a few years through the establishment of a government-owned poultry processing plant in Poona. The manufacture of moulded paper egg trays (which commenced in India in 1967) also influenced egg marketing significantly. Egg breakage during transport decreased from 17 to 2.5 percent, which on a national basis could mean a saving of 840 million eggs per year.

Conclusions

Limited supplies of grains and vegetable proteins have led to competition between animals and man for these products, so that the question of the efficiency of different kinds of animals in converting feed into high-grade animal protein is vitally important. Where meat production efficiency is concerned, poultry are superior to pigs, which in turn are well ahead of ruminants. Feed conversion in respect of egg production is also superior to meat production from other farm animals, and is of the order of 1:2.7. The contribution of the poultry industry to world protein supplies in the last 15 years has been higher than that of all other animals in developed, developing and centrally planned countries, and shows the potential of poultry for sustained increases in the future.

REFERENCES

ABBOTT, J.C. 1973. *Proceedings of the Conference on Food Protein, Quebec City*, p. 59-80.

CLAYTON, J.A. 1975. *Poultry Industry*, May 1975.

FAO. 1973a. *Energy and protein requirements. Report of a Joint FAO/WHO Ad Hoc Expert Committee, 1971.* Rome.

FAO. 1973b. *Production yearbook 1972.* Rome.

FAO. 1973c. *Report of the fourth FAO Expert Consultation on Animal Genetic Resources (Poultry Breeding), March 1973, Nouzilly, France.* Rome.

FAO. 1974. *Production yearbook 1973.* Rome.

FAO. COMMITTEE ON COMMODITY PROBLEMS. 1973. *Report of the sixteenth session of the Intergovernmental Group on Grains to the Committee on Commodity Problems.* Rome. CCP: 73/11.

FAO. COMMITTEE ON COMMODITY PROBLEMS. 1974. *Estimates of production and trade for 1973 and forecasts for 1974. Oils/fats and oilcakes/meals.* Rome. CCP:OF/ST 74/CRS 3.

FAO. COMMITTEE ON COMMODITY PROBLEMS. 1974. *Problems of aflatoxins in oilseeds and oilcakes: summary and analysis of questionnaire replies.* Rome. CCP:OF/Cons 74/4.

MCARDLE, A.A. 1969. *Interim report submitted to the Government of India on poultry development.* Rome, FAO. AN:IND/68/9.

PANDA, J.N. 1974. Poultry industry in India. In *Indian poultry industry yearbook 1973/74.*

U.S. DEPARTMENT OF AGRICULTURE. ECONOMIC RESEARCH SERVICE. 1968. *Comparison of returns to poultry growers, under contract, operating independently.* Washington, D.C. Marketing Research Report 814.

WALKER, T. 1974. Agricultural products and markets. *In* Organisation for Economic Co-operation and Development. *Nitrogenous products of industrial origin for animal feeding.* Paris.

WINSCH, V.A. 1973. *Proceedings of the Conference on Feed Protein, Quebec City*, p. 213-229.

news and notes

Fourth World Conference on Animal Production

The Organizing Committee of the Fourth World Conference on Animal Production to be held in Buenos Aires, Argentina, in 1978, invites comments from readers of *World Animal Review* on the proposed programme for the Conference.
The theme will be the effectiveness of animal production systems. It will be developed from a biophysical and socio-economic viewpoint.
The programme outline for the technical sessions proposed is as follows:

1.0 — Animal production systems in Latin America: structural characteristics as determined by the current distribution of the means of production; relationships between prevailing ecological conditions and the technologies in use.
2.0 — Effectiveness of animal production systems.
2.1 — Biophysical factors: the elaboration of usable technologies, based on biophysical information, for the production and distribution of animal products.
2.1.1 — Production systems: current methods of production using existing resources in their natural or improved form; models of new production systems that may be employed and the methodology to integrate technical and scientific knowledge in the biophysical fields.
2.1.2 — Available livestock and their utilization: the possible use, in each region, of native and exotic stock in terms of breeding, physiology, health and animal products.
2.1.3 — Available feeds and their utilization: current and potential productivity of conventional and new feed resources and their efficient use.
2.2 — Socioeconomic factors: historical and cultural characteristics and structural and financial conditions affecting the implementation of livestock development programmes and the effectiveness of production systems.
2.2.1 — Systems methodology: evaluation of existing techniques for the development of animal production systems to be used in the formulation of livestock development programmes.
2.2.2 — Institutional organization: review of institutional aspects limiting the implementation of livestock development programmes.
2.2.3 — Communication: analysis of the methodology involved in educating livestock producers to employ new technology.
2.2.4 — Commercialization: the attainment of a balanced relationship between the production and consumption of animal products.

Comments on the proposed programme outline may be sent directly to Dr. Filemón Torres, President, World Association for Animal Production, Dpto. de Producción Animal, Balcarce, Pcia. de Bs. As., Argentina.

Conference on tick-borne diseases and their vectors

The University of Edinburgh, Centre for Tropical Veterinary Medicine, has announced an international conference on tick-borne diseases and their vectors which will be held at the University from 27 September to 1 October 1976. Papers will be presented in the following categories: tick biology and tick control, the epidemiology of important tick-borne diseases, and recent advances in research on these diseases and their vectors.
Those wishing to receive information about this conference are asked to write to:

Dr. D. Branagan, Conference Secretary,
Centre for Tropical Veterinary Medicine,
University of Edinburgh,
Easter Bush, Roslin,
Midlothian, Scotland.

Twentieth World Veterinary Congress

This Congress, which was attended by some 3 000 veterinarians, took place in Thessaloniki, Greece, from 6 to 12 July 1975. More than 900 papers and short communications were presented.
In the first of the plenary sessions, Dr. Carlos L. de Cuenca (Spain) and Dr. H.A. Jasiorowski (FAO) dealt with meat consumption and production in the world, stressing hindrances and suggesting solutions to this vital and urgent problem for all mankind. In another of the plenary sessions on man, animal and environment, Dr. M.M. Kaplan (WHO) covered the problems of surveillance for adverse environmental effects on man and animals, emphasizing the importance of establishing surveillance mechanisms and the formulation and implementation of appropriate early warning systems. In the plenary session on comparative studies in biochemical research, Dr. W.I.B. Beveridge (Australia) and Dr. A. Mayr (Federal Republic of Germany) spoke on comparative cancer and virus research; and Dr. D.G. Ingram (Canada) dealt with immune complex diseases of animals. Examples of this latter syndrome are equine infectious anaemia, bovine trypanosomiasis, African swine fever, murine lymphocytic chroriomeningitis and aleutian disease in mink. In chronically infected animals, immune complexes of microbial antigen, antibody and complement are formed, and deposited on the red blood cells and in various tissues, resulting in inflammatory reactions and organ damage.
Eighteen different sections covered the broad field of veterinary medicine, including themes of general professional interest such as the international movement of domestic and wild animals, new trends in veterinary teaching, continuing education of veterinarians, legal pitfalls in veterinary practice, the use of auxiliaries in veterinary services, and the role of the veterinarian in the developing countries. A paper on the campaigns conducted from 1962 to 1975 against exotic foot-and-mouth disease in Turkey and in adjacent countries in southeastern Europe, with the assistance of FAO and its European Commission for the Control of Foot-and-mouth Disease, was presented by Dr. G.M. Boldrini (FAO).
The social events were well organized, reflecting Greek hospitality and friendliness in a perfect atmosphere of ancient culture, fine sunny weather and a beautiful landscape, one of the highlights being the excursion to the ancient city of Philippi in Macedonia.
The proceedings, with complete texts of papers and communications, will be published within six months. They may be obtained from the Organizing Committee, Aristotelian Panepistimion, Box No. 112, Thessaloniki, Greece. The next World Veterinary Congress will take place in Moscow in 1979.

Tropical Feeds - Feeds Information Summaries and Nutritive Values

Bo Göhl. FAO Feeds Information Centre, Animal Production and Health Division, FAO, Rome, 1975. 661 pages, numerous tables, 519 references. WS/F4915. (In English.) Available against handling charge.

This is an unedited typescript version of feeds information summaries and nutritive values prepared by Mr. B. Göhl during a period of work in the FAO Feeds Information Centre. The Centre's object is to collect information which will be of help to animal nutritionists and others who seek to make use of feeds, or potential feeds, in developing countries. Useful information is provided on about 700 species of plants that may be edible for animals, and their proximate analyses. For many of these feeds digestibility coefficients and TDN contents are given; the amino acid composition of almost 200 feeds is also provided. For materials which may be included in poultry diets metabolizable energy contents for poultry are listed. Less information could be provided on the detailed mineral composition, but what was available is included.

The sources of the information provided are listed, and the reader is referred to many summaries which provide more extensive coverage of particular feeds. Due to delays in publication, for which the author was in no sense responsible, information published in the last five years or so is not included. For this reason a number of valuable surveys of pasture plants in tropical Australia are not covered; neither is adequate recognition given to the improved methods of analysis now being increasingly used.

In a perfect world, rations for farm stock would always be based on the analysis of samples of the available feeds, at the very least coupled with digestibility trials, done *in vivo* or *in vitro*. Every attempt should be made to increase facilities for feedingstuff analysis and measurements of nutritive values; until this is achieved, however, workers in many developing areas will have to rely on "book" values. This contribution is a bold attempt to fill a very large gap in the information available to animal nutritionists.

In introducing the monograph Dr. H.A. Jasiorowski has drawn attention to the International Network of Feeds Information Centres, of which that at FAO Headquarters is one, which collects worldwide information of the kind here provided.

C.C.B.

Animal industry groups in the Asian and Pacific region

Registry of Scientific and Technical Services for the Asian and Pacific region, P.O. Box 62, Jamison Centre, A.C.T. 2614, Australia, 1974. Second edition. 587 pages. (In English)

The Registry of Scientific and Technical Services is an intergovernmental organization established in Canberra, Australia, in 1968. The main work programme of this Registry is the preparation and publication of scientific directories. Six have been published to date. Free copies of each directory are given to those groups appearing in the directory with a view to promoting scientific and technical cooperation in the region. Copies are also sold internationally.

The information in this directory is set out in three main sections. The first lists the groups with details of their address, structure and function. The second is a two-part subject index. One part is organized under broad general headings: animal quarantine, cattle diseases, cattle management, cattle nutrition, etc.; the other under detailed specific headings: Aberdeen Angus cattle, acaricides, African swine fever, etc. The third is an index of organizations together with their groups that are included in the directory.

The information about groups includes, *inter alia*, the projects currently being undertaken by each group under topic headings. Cooperative projects with which formal links have been established are listed. Facilities for training and training programmes as well as staff resources and sources of finance are also included.

P.M.

The principles of horseshoeing

Karl Douglas Butler Jr. 1974. First edition. 428 pages. Price US$19.95. (In English)

This is a very useful text book that has been published at a time when pleasure-horses are increasing in numbers and there is a great demand for horseshoers. It differs from other books of its kind in covering a wide spectrum of topics. The first section, entitled "Perspective," includes a brief account of the history of horseshoes and shoeing.

The technical chapters are generally excellent. The section on horse and hoof handling gives helpful hints not only for the student blacksmith but for horsemen in general. Advice on handling "spoiled" horses is spelled out step by step. The section on anatomy and physiology is well conceived and illustrated as are the following sections on normal shoeing, iron and forge work, corrective and pathological shoeing. It is worth mentioning that the author discusses in detail the controversial point of hot and cold shoeing. Although this book is primarily designed for North American conditions, the reviewer recommends it for publication in Spanish for the Latin countries which still have a high horse population. It would be of use to students, professional blacksmiths, veterinarians as well as to serious minded horse owners.

B.M.H.

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